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METAL PROGRESS

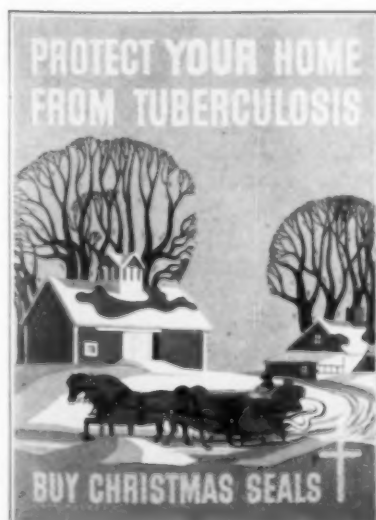
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In this article an effort is made to present the physico-chemical information concerning the carburization of iron by carbon monoxide in such a way as to be understandable to a metallurgist and useful to him in appraising and improving his own practice

Fundamentals of Good Carburization

WHILE a great deal of empirical carburizing practice exists in industry, the principles, chemical and physical, underlying the phenomenon are known, though they have not received the consideration due them. Of course, the practical heat treater doesn't care much about the *how* and the *why* of a good case as long as he has one that will pass the specification—or sometimes “just as long as he has a case”.

With a better understanding of gas-metal reactions and the behavior of carbon in the iron, one can produce cases (carburize) with ease and with certainty, and thereby control the type of case by suitable changes in the variables associated with the operation. For example, the element of time is now of considerable importance. If a gear can be carburized satisfactorily in 6 hr., why do it in 12?

Types—Carburizing, or more specifically casehardening, is done commercially by three methods:

1. Solid or pack carburizing
2. Gas carburizing
3. Liquid or fused salt carburizing

It is possible to consider methods No. 1 and 2 together, for it has been long established that both depend on the action of CO:CO₂ mixtures. Strictly speaking, liquid carburizers also fall into this category, since the CO dissolved in the fused salt probably does the work; however, this method will not be included in the present discussion.

With solid carburizers the carbonaceous material reacts with the air supply to form a mixture of CO and CO₂, which mixture then reacts with the steel surface according to the equation:



The behavior is over simplified in the above equation. For better carburization, “energizers” are usually added to the carbonaceous material; their role appears to be one of catalysts rather than reactants.

In gas carburizing, it is quite obvious that CO:CO₂ mixtures proceed as indicated in equation (1).

Gas mixtures are prepared in numerous ways. Natural gas as such is an excellent carburizer, but its high methane content leads to soot deposition. [See page 926.] Atmospheres have been prepared by volatilization of turpentine, gasoline, aniline, and benzene. Gas mixtures have been prepared by passing hydrogen, nitrogen, and even air through these liquid hydrocarbons. City gas is often used but it must be dried and often enriched. The most economical gases are prepared from partially or completely burned natural gas. Flue gas mixed with natural gas has been used, and flue gas passed through heated charcoal also has been successful.

In all these types of gas production the higher hydrocarbons break down to methane, CH₄, carbon and hydrogen. Carburization can then be said to proceed by a second reaction, in addition to equation (1) above:



However, the most important commercial

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Fig. 1 — Experiment Shows That at Carburizing Temperatures, Practically All the CO₂ Reacts With Carbon to Form CO. Data from Table I

reaction is that of equation (1) and for this reason it will be the one considered here. Furthermore, to bring this simplified discussion within bounds, it is assumed that moisture, oxygen and H₂S are absent.

Equilibrium — Before discussing equation (1) it should be recalled that it is the behavior of the gas phase which determines how much the iron will be carburized — or even decarburized. The governing reaction is

$$2\text{CO} \rightleftharpoons \text{CO}_2 + \text{C} \quad (3)$$

and its behavior or shift with temperature and pressure (total and partial) is well known from precise studies extending back 40 years.

The change in concentration of the CO and CO₂ with temperature, as determined by analysis, is given in Table I. The per cent of each gas is, in this binary mixture at atmospheric pressure, equivalent to the corresponding partial pressures. Equilibrium constant is determined from the latter by the equation $K = \frac{(p_{\text{CO}_2}) (C)}{(p_{\text{CO}})^2}$, and since the effective concentration (activity) of pure solids is assumed to be unity, the equation is written as follows:

$$K = \frac{p_{\text{CO}_2}}{(p_{\text{CO}})^2}$$

Change with temperature in the concentration of CO and CO₂ and the equilibrium constant is shown better in Fig. 1 and 2, which indicate the tremendous effect of temperature on this reaction. The most important thing to notice is that most of the CO₂ has reacted to form CO when equilibrium is established at high temperatures (above 900° C.). Therefore, in box carburizing at 1700° F. there are 98 parts of CO to 2 parts of CO₂.

It is the change in equilibrium caused by these

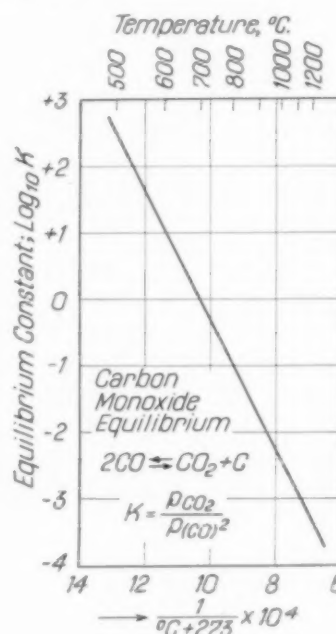
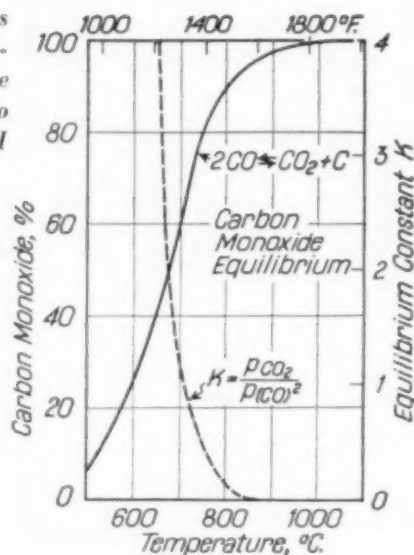


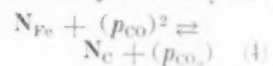
Fig. 2 — Logarithm of Equilibrium Constant for Equation $2\text{CO} \rightleftharpoons \text{CO}_2 + \text{C}$ Plotted Against Reciprocal of Absolute Temperature; Useful for Estimating Very Small Values at High Temperatures

variables of pressure and temperature that makes the above reaction yield to or abstract carbon from a system. When a metal such as steel is introduced into the system the gas will yield carbon to (carburize), or abstract carbon from (decarburize) the steel, depending on the conditions.

While the carbon monoxide equilibrium governs the carburization process, it does not actually represent the true state of things, because another component, iron, is added and the actual carburization equation becomes the one noted at the outset, namely



This reaction can be written in terms of mol fractions for the solids and partial pressures for the gases, so that a consistent system of concentrations can be used in the study of this system:



[In equation (4) mol fraction, N, in a solid solution is defined as

Table I — CO:CO₂ Equilibrium at Atmospheric Pressure*

TEMPERATURE		CONSTITUENTS		PARTIAL PRESSURES		EQUILIBRIUM CONSTANT	
°F.	°C.	% CO ₂	% CO	p _{CO₂}	p _(CO) ²	K	log ₁₀ K
842	450	98	2	0.98	0.0004	2.4 × 10 ³	3.380
932	500	95	5	0.95	0.0025	3.8 × 10 ²	2.580
1022	550	89	11	0.89	0.0121	7.3 × 10	1.863
1112	600	77	23	0.77	0.0529	1.4 × 10	1.146
1202	650	61	39	0.61	0.1521	4.0	0.602
1292	700	42	58	0.42	0.3364	1.2	0.079
1382	750	24	76	0.24	0.5776	0.4	-0.398
1472	800	10	90	0.10	0.8100	1.2 × 10 ⁻¹	-0.921
1562	850	6.23	93.77	0.062	0.880	7.0 × 10 ⁻²	-1.155
1652	900	2.22	97.78	0.022	0.956	2.5 × 10 ⁻²	-1.602
1742	950	1.32	98.68	0.013	0.974	1.3 × 10 ⁻²	-1.886
1832	1000	0.59	99.41	0.006	0.988	6.0 × 10 ⁻³	-2.272
1922	1050	0.37	99.63	0.004	0.992	4.0 × 10 ⁻³	-2.398
2012	1100	0.15	99.85	0.0015	0.996	1.0 × 10 ⁻²	-3.000
2192	1200	0.06	99.96	0.0006	0.999	6.0 × 10 ⁻⁴	-3.222

*Data to 800° C. from Boudouard, Ann. Chem. Phys., Vol. 7, 1901, p. 24, and at higher temperatures from Rhead and Wheeler, J. Chem. Soc., Vol. 97, 1910, p. 2178.

$N_1 = \frac{n_1}{n_1 + n_2}$, where n is the number of mols of each component. Also, $N_1 + N_2 = 1.$

From equation (4) the equilibrium constant is

$$K = \frac{(N_C)}{(N_{Fe})} \cdot \frac{(p_{CO_2})}{(p_{CO})^2} \quad (5)$$

Experimental data acquired by numerous investigators of the iron:carbon:oxygen system have been recalculated so that K could be ascertained, and the results are in Table II.

From these values of K the ratios of $CO:CO_2$ in equilibrium with steel were obtained. The plotting of the two ratios in equation (5), namely, $(CO_2):(CO)^2$ vs. $(N_C):(N_{Fe})$ as rectangular hyperbolas on ordinary graph paper is difficult, for the curves are hard to draw accurately and interpolation can be very inaccurate. A more practical way is to plot the ratios on log-log scales so that the resulting curve becomes a straight line. This is shown in Fig. 3, below, on which the CO_2 and CO contents are given which are in equilibrium with the carbon in the steel at vari-

ous temperatures.

The utility of this figure is easily seen: To carburize a 0.20% C steel at 925° C. (1700° F.), the usual carburization temperature, up to 1.00% carbon in the outer layer (point A on the diagram) an atmosphere containing 2.2% CO_2 and 97.8% CO is required. A higher CO concentration will continue to carburize up to the limit of solid solubility; for instance a CO content of 99% at

Table II — Equilibrium Constant of Equation (1)

TEMPERATURE			EQUILIBRIUM CONSTANT: $\frac{(N_C)}{(N_{Fe})} \cdot \frac{(p_{CO_2})}{(p_{CO})^2} \times 10^3$					$\log_{10} K^*$
°F.	°C.	$10^3 T$ (Abs.)	(a)	(b)	(c)	(d)	Average	
1382	750	9.8	11.9	10.7	6.25	...	9.6	-2.018
1472	800	9.3	5.9	3.9	2.78	...	4.2	-2.377
1562	850	8.9	3.4	1.9	...	3.1	2.8	-2.553
1652	900	8.5	2.6	1.02	0.93	1.5	1.5	-2.824
1742	950	8.2	1.35	0.60	...	0.94	0.96	-3.018
1832	1000	7.8	0.85	0.36	0.36	0.58	0.54	-3.268
1922	1050	7.6	...	0.24	...	...	0.24	-3.620
2012	1100	7.3	...	0.16	0.28	...	0.22	-3.658

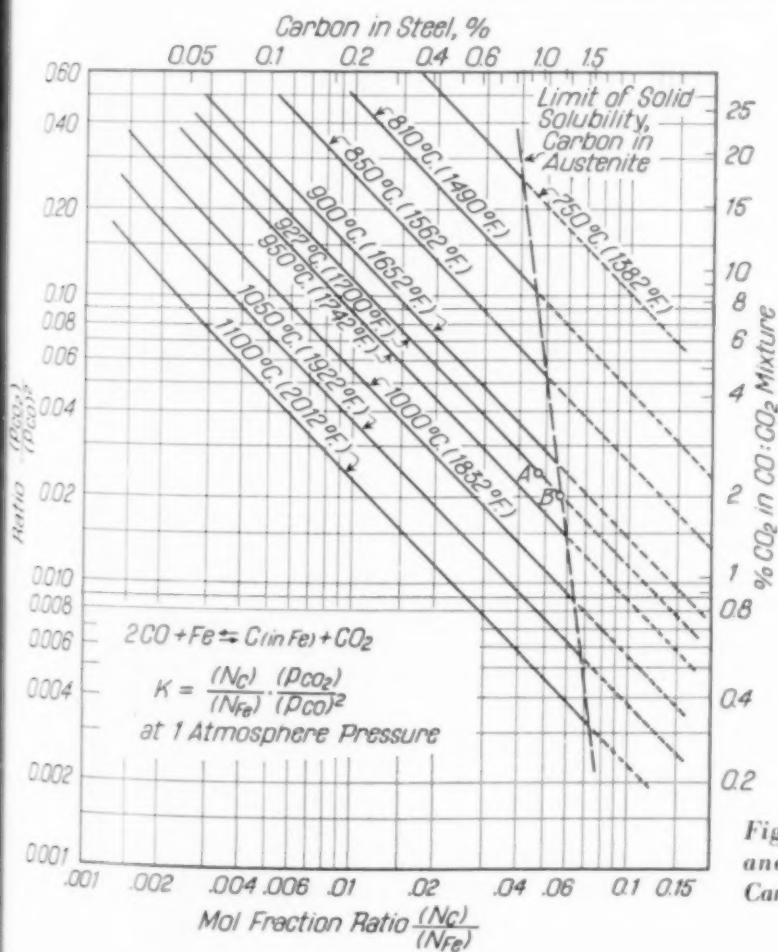
(a) G. Takahashi, Sci. Rep. Tohoku Imp. Univ., Vol. 15, 1926, p. 159.

(b) A. Bramley and H. D. Lord, J. Chem. Soc., 1932, p. 1641; also A. Bramley and A. Jinkings, Iron Steel Inst. (London), Carnegie Schol. Mem., Vol. 18, 1929, p. 1.

(c) A. Johansson and R. von Seth, J. Iron Steel Inst. (London), Vol. 112, 1926, p. 295.

(d) M. L. Becker, J. Iron Steel Inst. (London), Vol. 121, 1930, p. 337.

*Note that the logarithm of 9.6×10^{-3} or 0.0096, for example, is written not as an engineer would write it (namely, 7.982—10) but in its arithmetical value, that is, -2.018. The average experimental values of the last column are approximated by the straight line relation: $\log_{10} K = -8.43 + (6560 \div \text{absolute temperature})$.



1700° F. is in equilibrium (theoretically) with a considerably higher carbon content than is allowed by the solubility limit of carbon in iron at that temperature (1.20% carbon, noted as point B on Fig. 3), so that a slight excess of carbon will then be deposited as soot.

On the other hand, to prevent decarburization at 1700° F. of a steel having 1.00% carbon in the outer layers, the atmosphere must be maintained at 97.8% CO , assuming it to contain nothing but CO and CO_2 . If the proportionate amount of CO_2 increases and CO decreases, the steel would be decarburized. It is because of such actions that the CO content in gas carburization should be kept as high as possible. Thus, small change in CO or CO_2 can cause large changes in the carbon content of the case. It is because of this that pack carburiz-

Fig. 3—Curves Showing Contents of CO and CO_2 in Equilibrium With the Carbon in Steel at Various Temperatures

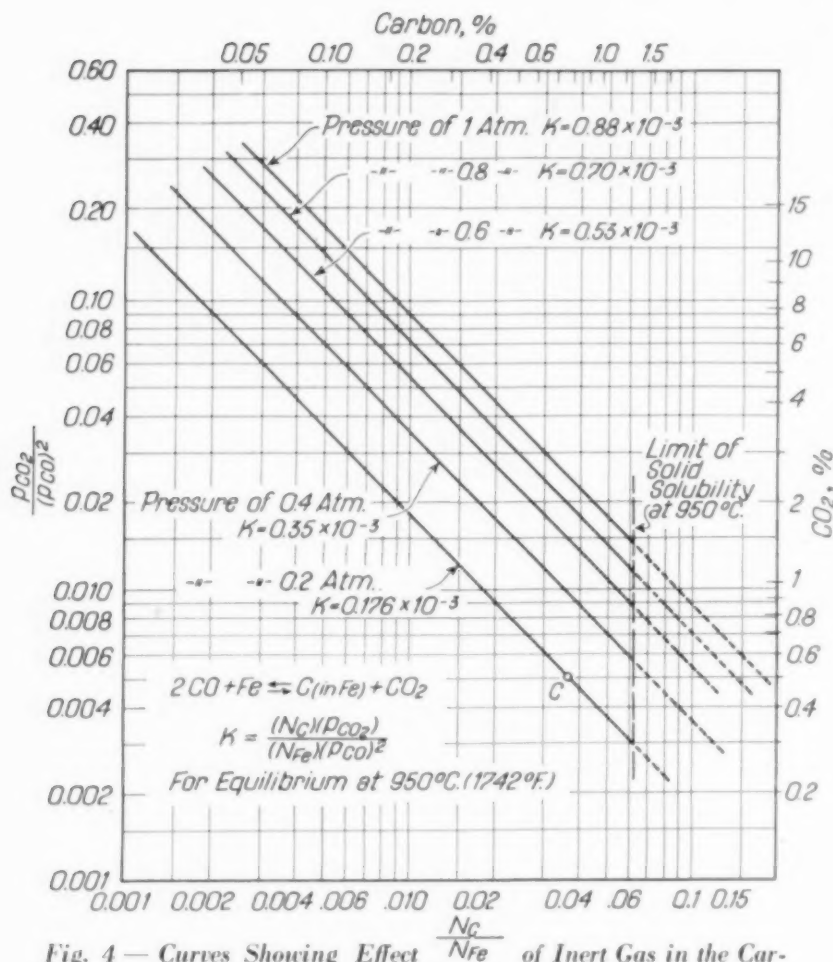


Fig. 4 — Curves Showing Effect $\frac{N_c}{N_{Fe}}$ of Inert Gas in the Carburizing Mixture (That Is, of Partial Pressure of CO+CO₂ Gases)

ing is more foolproof in the sense that it requires no adjustment of gas composition.

To take the example above, the amount of CO in equilibrium with CO₂ in contact with the carbonaceous material in the box is 98.2% CO and 1.8% CO₂ at 925° C. (1700° F.). [These values are not shown on Fig. 3 but may be estimated from the equilibrium constant given in Fig. 2 by the equation $K = \frac{1-X}{X^2}$ where X is the partial pressure of CO. A rough estimate of the CO and CO₂ content is possible from the data in Table I.] These gases are rich enough in CO to react with the iron imbedded in the carburizing material to form the system



From Fig. 3 one can see that the steel would be in equilibrium with such surroundings at 1700° C. when the surface layers are saturated with carbon, that is, the austenite contains about 1.20% C (Point B). At higher temperatures, with correspondingly lower concentration of CO₂ in equilibrium with the carbon, the saturation limit is reached before the gas can reach the theoretical equilibrium with the iron. In this way the pack carburizing method is foolproof when compared to gas carburizing.

Temperature, of course, has a very important effect on the gas equilibrium as can well be appre-

ciated from Fig. 3. More CO is necessary for equilibrium with a certain carbon content in a steel as the temperature rises. This is also shown in the following table:

Gas Composition in Equilibrium With a 1.00% Carbon Steel

° F.	° C.	% CO	% CO ₂
1472	800	91	9
1562	850	95	5
1652	900	97	3
1742	950	98.3	1.7
1832	1000	99.0	1.0

The curves shown in Fig. 3 are drawn for a total pressure of one atmosphere, and in which the partial pressures of CO and CO₂ are alone considered. The usual picture is complicated by the presence of nitrogen and hydrogen, which means that while the total pressure of the CO, CO₂, N₂, and H₂ is one atmosphere, the combined pressure of the CO and CO₂ is only a fraction of that. However, curves as shown in Fig. 3 can readily be plotted for any partial pressure of CO plus CO₂.

The effect of pressure at a given constant temperature (950° C.) is demonstrated in Fig. 4. This figure has five inclined lines showing that as the total pressure of CO and CO₂ decreases from 1.0 atmosphere to 0.2 atmosphere the greater is the amount of CO required to keep a steel of a given composition from decarburizing. This follows from the relation that

$$K = \left(\frac{N_c}{N_{Fe}} \right) \left(\frac{p_{CO_2}}{p_{CO}} \right) \left(1 + \frac{p_{CO_2}}{p_{CO}} \right) \div P$$

which is derived from equation (5) by multiplying through by P and by the proper substitution of $P = p_{CO} + p_{CO_2}$.

For example, if a steel is heated at 1742° F. in an atmosphere which has a composition of 20% CO and 0.1% CO₂ and balance of inert nitrogen the low carbon steel can still be carburized. In this case the partial pressure of CO is 0.20 atmosphere and of CO₂ 0.001; the total pressure of these two is 0.201 atmosphere, and the CO is 99.5% of the active CO + CO₂ mixture, and the ratio $\frac{(p_{CO_2})}{(p_{CO})^2}$ is

Table III—Effect of Moisture in Carburizing Gas on the Carbon in Steel at 930° C. (1705° F.)

% C IN STEEL	ANALYSIS OF ATMOSPHERE					
	H ₂ O	CO ₂	CO	H ₂	CH ₄	N ₂
1.34	0.13	0.0	20.6	38.6	0.9	39.9
.94	0.26	0.0	20.4	39.0	0.7	39.9
.64	0.50	0.0	20.1	39.3	0.5	40.1
.20	1.80	0.4	19.7	35.7	0.7	43.5

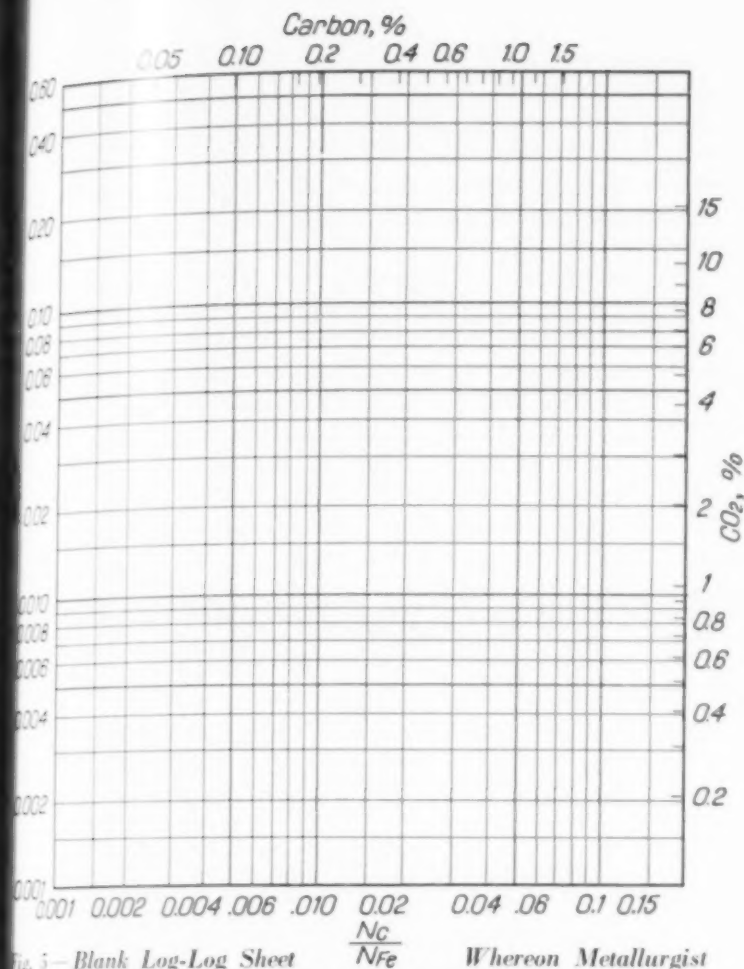
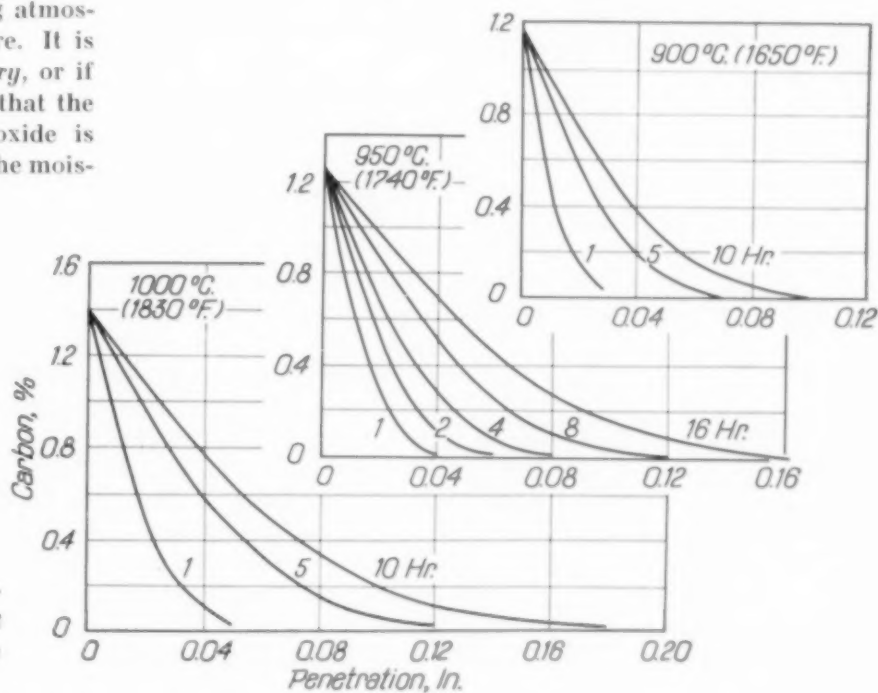


Fig. 5—Blank Log-Log Sheet Whereon Metallurgist Can Plot Lines Showing Conditions of Partial Pressure (Composition) and Temperature Existing in His Own Carburizing Practice

0.005 or 0.005. From point C on Fig. 4 it will be seen that 0.5% CO_2 at 0.2 atmosphere and 950° C. is in equilibrium with a steel of 0.8% carbon, so that this gas will carburize our low carbon steel up to that amount.

Moisture — There is one important item which will defeat the realization of a carburizing atmosphere and that is the presence of moisture. It is extremely important for the gases to be *dry*, or if they are not dry to adjust the mixture so that the carburization action of the carbon monoxide is greater than the decarburization action of the moisture. Exactly how some moisture can defeat good carburization practice is indicated in Table III, borrowed from J. V. GIER's paper before the American Chemical Society's Symposium on Furnace Atmospheres for Metallurgical Purposes (1940). In pack carburizing it is also essential to keep the compound dry; absorption of moisture during humid weather by loose carburizer, stored under cover, has caused trouble.

Fig. 6—Effect of Time on Penetration of Carbon Into Iron at Three Representative Temperatures



Formation of the Carburized Layer

Of course an understanding of the reaction of a gas with steel is only about half the problem. After carbon has been deposited from the gas phase it has a definite behavior in the metal. The rate at which this added carbon migrates into the steel is the controlling factor in obtaining good cases. The type of case obtained, the thickness, and carbon gradient—all will depend on time of carburization and temperature of the work.

One way of determining the penetration of carbon into the steel after it has been deposited from the gas phase is to machine off thin layers of material from the carburized surface inward, analyzing each layer for carbon. If, then, a penetration curve is plotted, showing the percentage of carbon in each layer at the corresponding depth, the type of case can be studied. Typical penetration curves for carbon-free iron are plotted in Fig. 6. These curves can be plotted from experimental data or can be calculated from a knowledge of the diffusion coefficient of carbon as will be indicated presently. For instance, at top right of Fig. 6 penetration curves are drawn for three different carburizing times at 900° C. (1650° F.) with

the very surface being saturated to the limit of solid solubility of carbon in iron, either by pack carburizing or by using a properly controlled gas atmosphere.

These curves illustrate the common knowledge that a steep gradient is characteristic of low car-

burizing temperatures; higher surface carbon contents result with more gradual gradients at higher temperatures, and the gradient is flattened with longer time. The depth of case is related to the carbon gradient, and a judicious choice of time and temperature will govern the correct case. If a case is too thin it may spall or crack off (exfoliation) and if it is too deep the heat treatment, in addition to added expense, may not retain the desired physical properties in the core.

Diffusion—The quantitative treatment of the kinetics of carburization is basically dependent upon the diffusion of carbon. This aspect will now be very briefly considered.

The behavior of carbon can be expressed by Fick's law. The solution arrived by van Orstrand and Dewey (U. S. Geological Survey, Professional Paper No. 95) can be used to calculate carburization curves. The solution is:

$$C = C_0 \left[1 - \phi \left(\frac{x}{2\sqrt{Dt}} \right) \right] \quad (6)$$

where C is the composition at point x in %; C_0 is the concentration of the diffusing substance (carbon, in this case) at the immediate surface, which remains constant at a given temperature and constant composition of the gas phase; D is the diffusion coefficient (sq.cm. per sec.); t is the time in sec.; ϕ is the Gauss error function; and x is the penetration in cm.

The above equation (6) requires a table of Gauss

error functions and a knowledge of the diffusion coefficient so that the effect of time and temperature on the carburization curve can be determined. Fortunately the diffusion coefficients of carbon in gamma iron are well-known from Wells and Mehl's work published in *Transactions of the American Institute of Mining and Metallurgical Engineers* in 1940. A few values are given below so that the curves may be calculated and the effect of time and temperature of carburization demonstrated. Actually equation (6) only gives a good approximation as far as the true case is concerned. For an accurate calculation, the variation of the diffusion coefficient with concentration must be taken into consideration.

Diffusion Coefficient at Various Temperatures

TEMPERATURE		D (SQ.-CM. PER SEC.)
800° C.	1470° F.	4.1×10^{-8}
900	1650	1.4×10^{-7}
925	1700	2.0×10^{-7}
950	1742	2.3×10^{-7}
1000	1830	4.1×10^{-7}

Wells and Mehl point out that the diffusion coefficient appears to be independent of grain size, low content of alloys that form austenitic solutions, and commercial impurities, so that it may be assumed that these factors are inoperative as

far as the present discussion is concerned. For example, the rates of diffusion of carbon in steel were identical in steels having 2500 to 3000 grains per sq.mm. and 30 grains per sq.mm. Nickel up to 1.9% and manganese up to 2.5% had no apparent effect on the diffusion coefficient when compared to pure iron. In the presence of carbide-forming elements, such as Ti, V, Mo, and Cr, the situation is different and complicated.

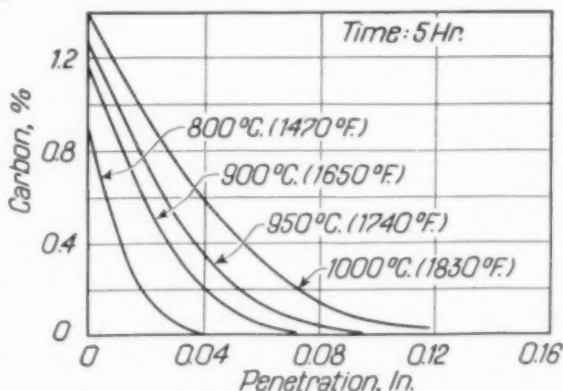


Fig. 7—Effect of Temperature on Penetration of Carbon Into Iron

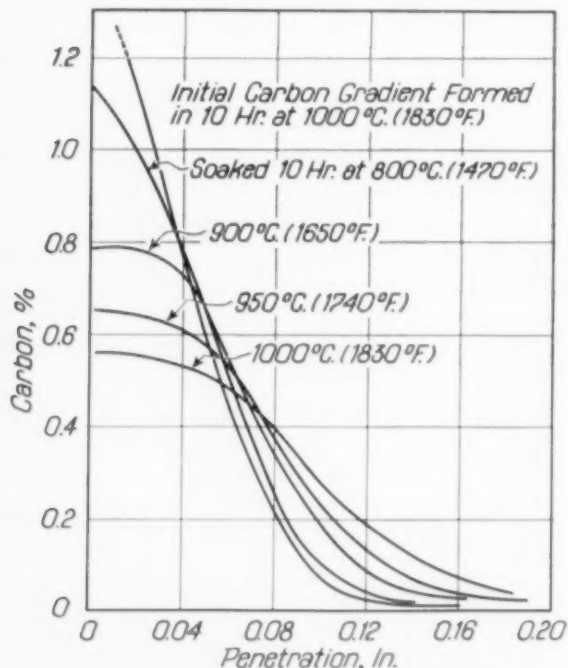


Fig. 8—Armco Iron Carburized to High Surface Carbon and Steep Gradient Was Diffused by Subsequent Soaking 10 Hr. at Indicated Temperatures, Thus Deepening the Case and Lowering the Surface Carbon. Bramley and Lord, Carnegie Scholarship Memoirs, British Iron & Steel Institute, 1929

The limiting carbon contents C_0 at various temperatures, used for calculating penetration curves, may be taken from the A_{cm} line in the iron-carbon equilibrium diagram, *Metal Progress*, October 1942, page 606. In order to compare the depth of the case in each of the instances plotted in Fig. 6, one may assume it as the penetration of the carbon to an arbitrary concentration—say 0.20% C. In actual practice the depth of case is where the carbon gradient reaches the carbon content of the steel being carburized. For the discussion below, it has been assumed that the steel being carburized has an initial carbon content of 0.20%, quite usual for carburizing steels.

Of course, the depth of the case is increased by extending the carburizing time, but it must be emphasized that doubling the time does not double the penetration. Actually to double the penetration, the time

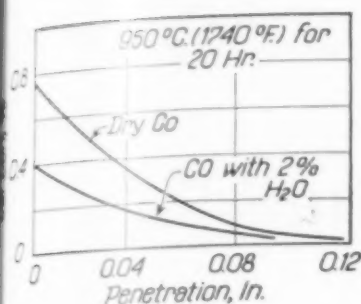


Fig. 9—2% Water Vapor in Slow Stream of CO Practically Halves the Carburization. Bramley and Jinkings, Carnegie Scholarship Memoirs, British Iron & Steel Institute, 1926

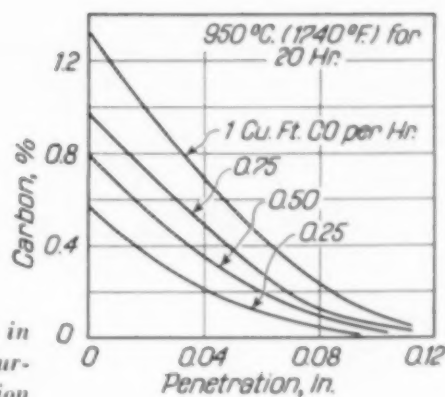


Fig. 10—Effect of Rate of Flow in Bringing Fresh Gas to Reacting Surface and so Improving Carburization

must be quadrupled. This is evident from the curves for 950° C. One can see that the penetration to the arbitrarily chosen limit of 0.20% C is as follows: 1 hr., 0.022 in.; 4 hr., 0.044 in.; and 16 hr., 0.088 in.

This exponential relation follows from equation (6) showing that the penetration is proportional to the square root of the time, a consequence of the \sqrt{Dt} factor. Therefore, if a penetration of 0.022 in. is reached in 1 hr. ($t = 1$), then twice the penetration (0.044 in.) is reached in 4 times the initial time or 4 hr. To treble the thickness we must carburize 9 hr.

The effect of temperature is demonstrated in Fig. 7, in which the case after 5 hr. at 800, 900, 950, and 1000° C. is plotted. It is evident from this curve that the depth is increased considerably by higher temperature, as would be expected. Furthermore, it should be noted that the amount of carbon in the outer layers is higher with increasing temperature, due to the increased solubility of carbon in saturated austenite.

Surface Carbon—Control of surface carbon is of great importance at the present time in ordnance work. While it would seem possible to control this concentration by establishing correct equilibrium between the steel and gas composition, this is not practical either because plant control is not accurate enough or because this would involve longer time cycles to reach substantial equilibrium. The most successful method is by carburizing to some higher amount and then diffusing the carbon in a neutral atmosphere (or with a protected material as by copper plating).

Bramley and Lord have carried out work to show how carbon can be redistributed in the material by further heating. See Fig. 8. In this work a sample of Armco iron was carburized 10 hr. at 1000° C. (1830° F.) in a CO atmosphere saturated with toluene. This material was then reheated to various temperatures for a period of 10 hr. in a stagnant CO atmosphere. Similar results were obtained by reheating the carburized bar in a dry nitrogen atmosphere. By reheating the specimens a redistribution of carbon occurs; the gradient is less severe and the actual penetration is greater.

By redistributing the carbon in this manner an alloy steel containing over 1.20% C, which on hardening might contain excess carbides and

retained austenite, can have its carbon reduced to around 0.60% C by reheating at 950° C., after which the response to heat treatment for certain applications is much better.

In the discussion of the gas reactions, it was pointed out that moisture can be extremely detrimental to a good case. In one extreme, excessive moisture can even prevent carburization and lead to decarburization, but usually moisture causes a poor case in the sense that the case is low in carbon. In Fig. 9 we see what moisture can do to a case. The example cited is for a flow of 0.5 cu.ft. per hr. of CO (a flow too low to cause saturation in the outer layers) and illustrates how the surface carbon can be reduced by moisture.

Flow of Gas—Another factor which must be considered in gas carburizing is the rate of flow. Assuming that the gas is of sufficient carburizing power, it may be that it is not brought to the surface in sufficient quantity to saturate it. In this instance a poor case will result. To illustrate this effect of rate of flow Fig. 10 has been drawn from the data of Bramley and Jinkings. If the rates of flow are too low, insufficient carbon is deposited in the metal surface. If, on the other hand, the flow becomes too rapid it will deposit soot, which may prevent carburization by excluding the oxide gas from the surface. High flows, besides being uneconomical, can also cool the furnace to temperatures at which a good case will not result.

Attention should also be called to the fact that proper position of the work is essential. For example, it is bad practice to stack up piles of gears, since poor contact between the atmosphere and the work prevents a uniform case. Circulation of the gas is of course necessary for good work. Such precautions apply as well to pack carburizing where an effort should be made to separate parts with at least a little compound.

It need not be emphasized that uniform temperature is of paramount importance in both the gas reaction and the formation of the case. Uniformity to within $\pm 10^\circ$ F. of the operating temperature is desirable; poor temperature distribution can cause heterogeneous carburization of the surface, in turn leading to large hardness variations and poor response to heat treatment.

War Products Consultation:

Substitute Steels

The Problem

Posed by a Canadian Manufacturer

WE HAVE A PROBLEM on our hands — in fact, we think it is quite a problem. Let us explain: We are making ordnance materials under rather high priority and the inspectors insist upon a 0.50% carbon chrome-vanadium steel for one of the parts. In fact, they are so insistent that we give it to them when we can get it.

However, by the process of elimination we have come to the conclusion that chrome-vanadium steel for this part is practically non-existent. Consequently, we are forced to seek a substitute.

Our information is that NE steels 8744 or 8749 are suitable substitutes for S.A.E. 6150, but this unsupported opinion is not good enough for the inspecting officers and we are looking for data that will prove our point.

The Proposed Solution

UNDOUBTEDLY the representatives of the armed services will be difficult to convince that there is anything quite so good as S.A.E. 6150. However, it will probably be necessary that some substitution be made.

A logical line of approach would be through the end-quench hardenability curves. Curves for S.A.E. 6150 and NE8744 and 8749 are shown at lower left on the opposite page, and the curves for the new steels straddle the old one. The curve for 6150 also divides, roughly, the space between NE9450 and 9440 on another of the diagrams. What this means is that the same part quenched in the same manner from the proper temperature will have — within narrow limits — the same surface hardness and same hardness at all points below the surface whether it is made of S.A.E. 6150, NE8744, NE8749, or NE9445. Since the last named has the lowest amount of critical alloying elements, it would be the best substitute.

The close proportionality between hardness and tensile strength is a metallurgical commonplace, so in the above paragraph read also "strength" for "hardness". Of course, there are other properties and fabrication characteristics to be regarded, but the satisfactory experience of a tractor firm which has processed more than 60 mill heats of the NE8000 and 9000 series may be accepted as indicative: This firm finds that very slight modifications of heat treating practice have been necessary. Substantial equivalence of NE steels with corresponding S.A.E. steels is found in the Jominy or end-quench test, tension tests, notched bar impact tests (generally the keyhole Charpy type), cold bend tests, and production tests of forging, annealing, machining, hardening, and the accompanying evaluations of distortion. Toughness of NE8739 and 8744 is exhibited by comparing notched bar values at $+75^{\circ}$ and -20° F.; rarely were the figures lowered 25% at the sub-zero temperature, and therefore the transition from notch-tough to notch-brittle is below even -20° F.

The truck and tractor industry has successfully substituted NE8749 for chrome-vanadium spring steels. One great advantage of the chrome-vanadium steel is, of course, its fine grain, induced by the vanadium, and its ability to stay fine grained despite any mistreatment in heat treating. Any substitute for it should be made in a steel which is definitely fine grained *after* normal heat treatment, even after a heat which might exceed the normal by 50 to 75°. Likewise, the endurance of springs is largely a function of the surface condition. Decarburization, pitting, or grinding cracks will ruin the life of a spring far more quickly than the lack of vanadium.

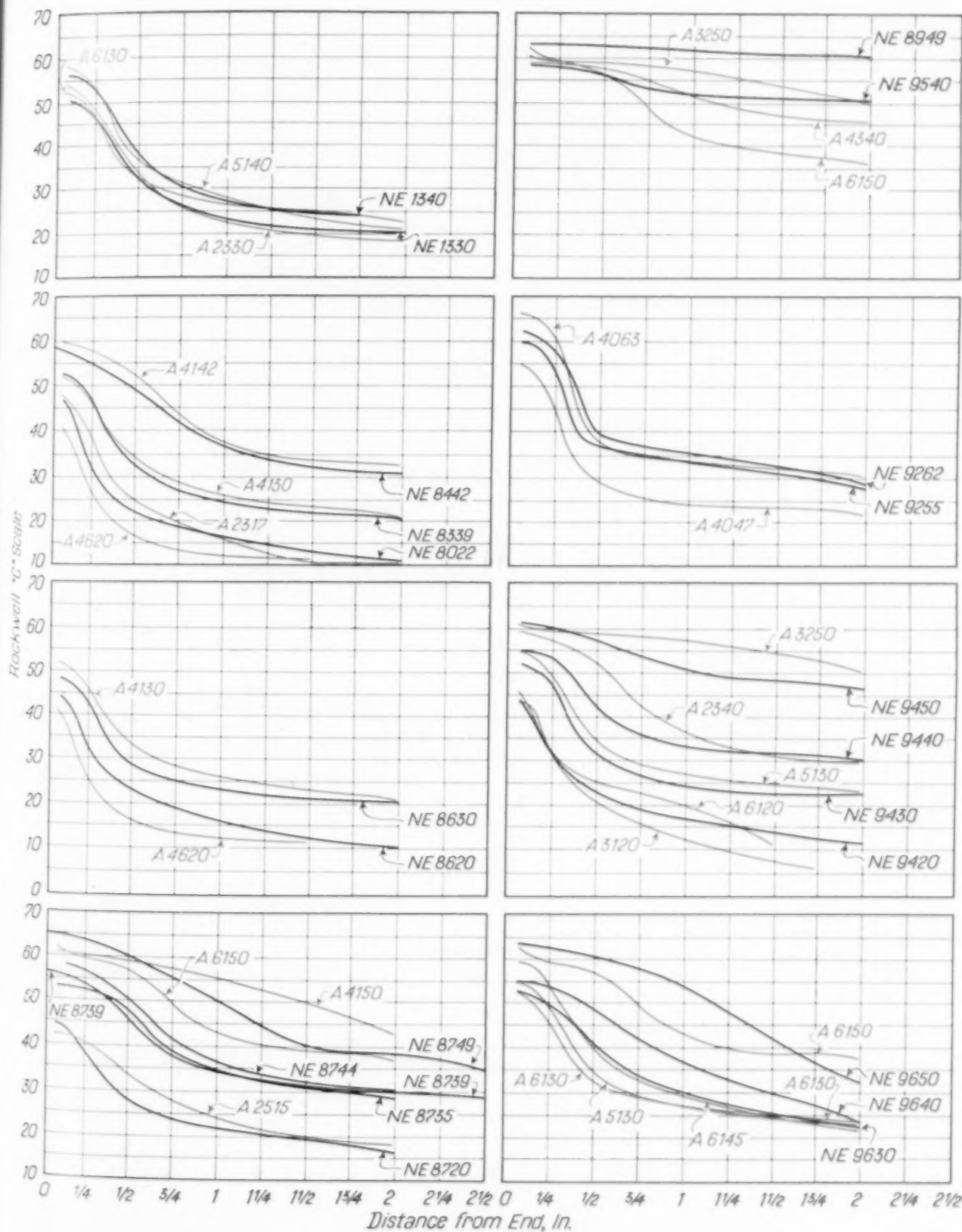
Finally, a recommendation as to general machinability and workability of NE8749 is in the fact that it has been substituted for 6150 in the operating rod handles in the Garand rifle, and will save in this one application 12,000 lb. of chromium and 4000 lb. of vanadium in the 1943 program. ☉

End-Quench Hardenability Curves of NE Steels

(Comparable S.A.E. Steels in Red; All Steels Fine Grained)

THERE IS A DEFINITE relationship between hardness and tensile properties—certainly for steels of equivalent grain size in the commonly used hardness range C-20 to C-45. Hardenability curves, which register the variation of hardness with depth below the quenched surface, are therefore excellent to compare a new steel against an

older, well-known steel. If they are similar, it follows that the major physical properties of a part made from a new steel will be practically indistinguishable from the same part made from the old steel, when both have similar grain size and proper heat treatment. (Data courtesy Technical Committee, American Iron & Steel Institute.)





S a u v e u r M e d a l i s t f o r 1 9 4 2



Benjamin Franklin Shepherd

A n E m i n e n t L i v i n g M e t a l l u r g i s t

■ EACH YEAR the past presidents of the  gather and consider whether some American is worthy of recognition for an outstanding achievement which has stimulated other organized work along similar lines to such an extent that a marked basic advance has been made in metallurgical knowledge" — in the words of the Sauveur medal award. As one of this group meeting during the 23rd National Metal Congress and Exposition last October in Philadelphia, Ben Shepherd was party to this discussion. The meeting broke up, apparently without a selection being made, as there is no obligation to name a recipient for any given year. However while he was absent from the proceedings for a few moments, the group had already selected him unanimously!

His achievement had been his pioneering work on the hardenability of high carbon tool-steel. It gave an accurate measure of that quality that had been recognized for generations, but only vaguely described as "body" or "personality". Shepherd's first publication on this subject was in *Metal Progress* for February, 1931, and it was entitled "Steel Personality", having just been presented to the  Western Metal Congress. In it he described how various toolsteels, indistinguishable by chemical analysis and microstructure, could be differentiated by the penetration of the hardness into stepped disks, properly heated and quenched. This "penetration-fracture" test (the "P-F test") was later supplemented by a series of fracture standards — samples of hardened toolsteel bars with grain sizes graded from fine to coarse in ten equal steps.

The test and the fracture standards have since become widely adopted. To fill the demand for the apparatus, he organized the Thermist Co., Inc., of Phillipsburg, N. J. This firm, described as "materials engineers", in addition to making thermocouples and thermocouple wire, has produced 150 of these fine precision standards which are sold at cost. They are as important to the user of high carbon steels as the foot rule is to the carpenter.



BENJAMIN FRANKLIN SHEPHERD has much in his life that is reminiscent of the Colonial scientist he was named after. He was born in Phillipsburg, N. J. in 1893. In 1911, after graduating from the local high school, he went to work in the Ingersoll-Rand plant as mail clerk. After his first year, he was promoted to the

physical laboratory. In his own words, "the laboratory staff comprised a man and a boy. I was the boy." He machined test bars and generally made himself so handy that when the man left for another job, the boy was promoted and ran the testing machine.

From that point, Shepherd rapidly developed a scientific bent. He introduced laboratory and plant work in pyrometry, metallography, in fact all the metal sciences, excepting chemistry, which was maintained as a separate department. For a boy without any scientific background, Shepherd mastered his work rapidly. He attributes his success largely to the many scientific organizations which he joined, getting everything out of the material, assistance and personal contacts these societies provided.

In 1919 he joined the newly organized American Steel Treating Society, and in 1920 — when the American Society for Steel Treating took over — became active in the Lehigh Valley Chapter, of which he was secretary-treasurer in 1923-24 and chairman in 1925-26. The national affairs of the Society also claimed his attention and he served as member of the Meetings and Papers Committee and the Publication Committee from 1924 to 1929. Shepherd was trustee during the critical depression years from 1931 to 1936, and during 1935 was national president of the Society, now called American Society for Metals. Other international engineering societies to which he belongs include the American Society for Testing Materials, Iron and Steel Institute of Great Britain, Institute of Metals of Great Britain, American Institute of Mining and Metallurgical Engineers, and the Society of Automotive Engineers. At one time, Shepherd was a vice-president of the Lehigh Valley Engineers' Society.

Through these organizations he gained a wide acquaintance with leaders in the metal profession. He read the technical papers, entered into the discussions and, using his inquiring turn of mind, began some original researches in the unsolved problems of science of metals. Now head of the Ingersoll-Rand combined laboratory setup, Ben Shepherd had all his company's laboratory facilities at his disposal. He wrote several papers on the carburizing of steel, a subject most important to his firm. Since the utility of both carburized parts and of shallow-hardening high carbon toolsteel rests on the same characteristic (hard surface and a strong tough core), Shepherd then turned to a study of hardenability. There was

no way to predict how deep a particular steel would harden, as there wasn't any equipment in the market to determine such characteristics. Hence the development of the penetration-fracture test (P-F test) and the set of fracture standards for which our Past-President is now honored.

Despite the exacting nature of his work as chief metallurgist of a great manufacturing organization, Shepherd has found time to travel rather extensively. On one trip to the Continent he visited every plant making hollow drill steel, excepting one in Norway. His travels took him to Sweden, to the Krupp Works in Germany, to Prague, Paris, Brussels, Liege, Vienna, Sheffield and Bristol. Almost jailed for taking pictures of an airport at Prague, lost for hours in Liege, Ben still had time to inspect plants and consult with Ingersoll-Rand executives on the Continent.

One trip into the field particularly impressed him with the hardship and problems experienced by workers using Ingersoll-Rand rock drilling machinery. He took a plane to a small town in the Mexican province of Durango. When it came time to leave, he traveled by mule, narrow-gage railroad, and automobile for three days to reach "civilization". He made 65 miles in 10½ hr. by truck, 136 the second day by narrow-gage train, and 150 the third day to reach the main line.

Through all these years, Shepherd has given more to his technical associates than he has received. He has traded his practical knowledge with the professors and doctors of science for a modicum of their theory. With the exception of two weeks shortly after the World War at Columbia University — where he attended a special course given by William Campbell for him and two other Ingersoll-Rand men — he has never had any formal study in the sciences. He is still giving his services wherever needed. Recently he was appointed a member of the Technical Advisory Committee on Toolsteel on the National Emergency Steel project of the War Production Board.

At the hamlet of Harmony, a little north of Phillipsburg, where he lives and manages his Old Mill Farm overlooking the peaceful Delaware, he has time to spare to help Mrs. Shepherd raise three young potential scientists. Ben doesn't really lose much money at farming his 180 acres, and has hopes of breaking even under a strict accounting procedure that Uncle Sam has asked him to use this coming season.

THEODORE A. SERRILL

Brittleness

in High Chromium Irons*

■ DIFFICULTIES in the production of high chromium irons of good mechanical properties are associated mainly with the absence of transformation, with resulting tendency to large grain size, and with the embrittlement which occurs in the range of temperature 750 to 900° F. At these temperatures the alloys undergo structural changes, not microscopically discernible, which result in extreme loss of ductility at room temperature. Fortunately, by rapid cooling the phenomenon is practically avoided and it is again fortunate that heating to a temperature slightly above the range completely restores the structure to the more ductile state.

This phenomenon is not observed in chromium-iron alloys containing less than about 20% of chromium, although brittleness of a different nature may be developed at lower chromium contents. This "875° brittleness" depends upon the chemical composition, as follows:

Chromium Content — In a series of steels containing 14.5 to 28.7% of chromium the embrittling effect extended over the range 750 to 925° F., the maximum embrittlement occurring at 875°. By increasing the time of exposure to the temperature, alloys of progressively lower chromium content began to be affected. In the one with 23.7% chromium, complete embrittlement occurred in 1000 hr. at 750° F., 100 hr. at 875 and 500 hr. at 925° F. At 1000° F. no embrittlement was caused even after 1000 hr.

After 1000 hr. at 875° no embrittlement occurred in steels with under about 15% of chromium, considerable embrittlement in chromium irons with 15.5 to 18%, and pronounced embrittlement in those with 19% and over. In standard impact test pieces a tendency to embrittlement was shown by a steel containing 15.18% of chromium but none in one containing 14.42%.

The presence of titanium, columbium, and carbon has little influence on the results, but 3% of manganese has the effect of raising the chromium content at which brittleness first appears by about 2%. The time required to produce embrittlement in alloys of given chromium content is lessened by the presence (*Continued on page 966*)

*Abstracted from *The Metallurgist* (Supplement to *The Engineer*), Dec. 26, 1941, page 43.)

Mass production of heat treated projectiles involves many problems, not least of which is the transportation of large tonnages of steel through heat treating furnaces. One successful solution of this problem is described in this article

Automatic Units for Heat Treating High Explosive Shells

EARLY in the production of high explosive shells for World War II it became evident that conservation of the manganese, specified in standard shell steels for depth hardness and machinability, would become a necessity. The need for increased shell strength was another requirement that had to be met by munitions makers. Previous to this time the necessary shell strength was obtained by air cooling or normalizing the shell forgings. However, with the manganese reduced and higher strength required, proper heat treating to meet the new conditions became the obvious answer to the problem. As pointed out in the discussion at the Philadelphia Convention (Metal Progress for November, 1941) the X-1340 steels which are satisfactory in the air cooled condition for medium caliber shells have been replaced with heat treated steels containing about two-thirds the manganese. This change in practice has also enabled the specification for strength and ductility to be improved.

Some months ago we were given the task of building a battery of furnaces for shell production, and after careful consideration of the many metallurgical, mechanical and economical factors involved, it was decided that the pusher type of furnace for the hardening operation synchronized with an automatic interior and exterior quench, followed by a continuous conveyor hot air recirculating draw furnace, would meet the requirements. The operation of these units has been eminently successful.

The Pusher Table

The heat treat is completely automatic from the time the forged and rough machined shells are loaded at the charging end of the unit until they are discharged from the cooling chamber.

In those installations where the foundation of the unit can be depressed so the pusher table is at working height above floor level, the shells are placed directly into the tubes manually. (See Fig. 1.) In other units, where the pusher unit is much further above floor level, a special automatic loading conveyor is used; in this latter type the shells are placed on the conveyor at floor level, conveyed upward, and then automatically discharged into the tubes in the proper time cycle.

The pusher table shown in Fig. 1 is quite simple, consisting of parallel extensions of the furnace tubes. Tops of these tubes are cut off so the shells being charged can be placed ahead of the pusher lug at the beginning of its stroke. During the stroke, the fresh shells are pushed into the hardening furnace tubes, and shove the

By D. H. Gardner
Metallurgist

and John Wallerius
Chief Engineer

Stewart Industrial Furnace Division
Chicago Flexible Shaft Co.

entire line ahead of them. Then, as the pusher returns to a starting position, new shells are loaded for another cycle. A standard hydraulic cylinder, either air or oil operated, and controlled by solenoid valves, is used for power.

The Hardening Furnace

In the hardening furnace proper the conveying tubes are designed to maintain proper alignment of the train of shells and to insure uniform heating. Each size of shell requires its own size of tube. These tubes are made in sections, the leading end anchored and the other end with a slip joint that allows for expansion and prevents the shells from catching. They are slotted top, sides and bottom with ample perforations to provide circulation of the furnace gases and yet retain adequate metal strength to carry the load. Individual rollers support each section of the tube. Shell tubes, rollers and supporting shoes are all of 12-27 chromium-nickel heat resisting alloy.

In most cases the nose opening of the shell is small enough to prevent slipping over the lug of the shell just ahead of it. However, in those shell designs where the two are likely to lock together, a small breaker bar is welded into the top of the discharge chute, automatically separating the shells just before they drop into the quenching fixture.

The hardening furnace may be fired with

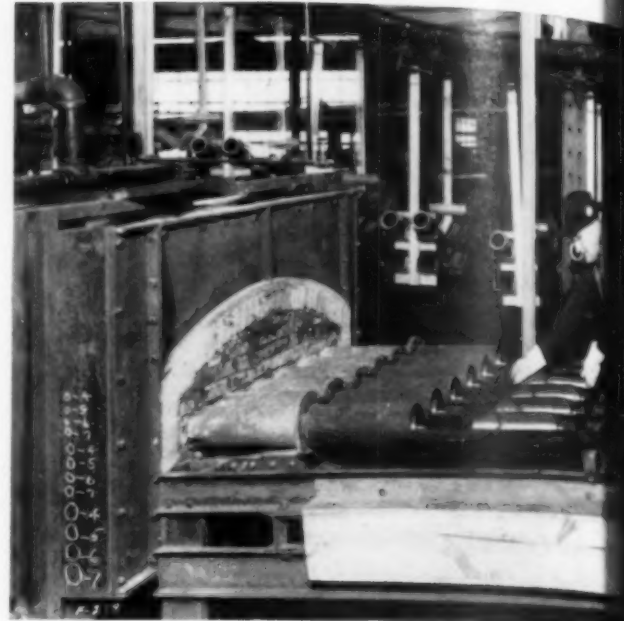


Fig. 1 — Loading Rough Machined Shells Into the Charging Furnace. Note that the six tubes are set on

either gas or oil fuel. In either case the burners are placed along the sides of the furnace, overfiring the heating zone along the arch of the furnace, the gases passing down the opposite side, underneath the tubes and out through flues placed at floor level. Since the tubes are elevated on piers above the floor this constant circulation of the heating gases, combined with the radiant effects of the hot arch and furnace walls, assures a uniform, thorough and rapid heating of the tubes. The high conductivity and diffusing action of the tubes as they take on this heat further assure the uniform heating of the shells, as is necessary for proper metallurgical results.

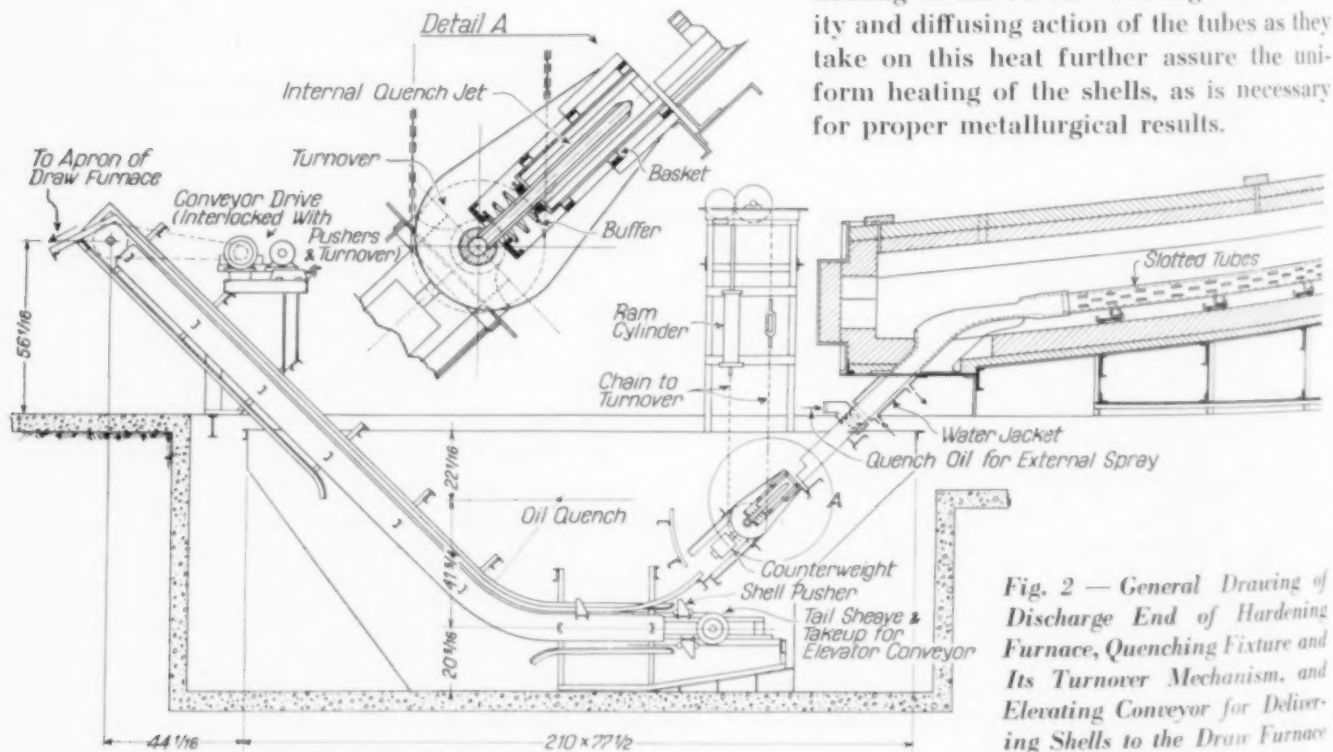


Fig. 2 — General Drawing of Discharge End of Hardening Furnace, Quenching Fixture and Its Turnover Mechanism, and Elevating Conveyor for Delivering Shells to the Draw Furnace

The combustion equipment is engineered for each fuel used. In the case of gas, standard tunnel type burners are used. With oil fuels, double atomizing oil burners are the rule.

The furnace is divided into three zones. The initial heating zone, comprising about 10 to 15% of the heating capacity, is manually controlled. The middle zone, for bringing the shell up to temperature and comprising 40 to 50% of the heating capacity, is controlled with indicating and controlling pyrometers operating the valve motors and proportioning valves. The final heating or soaking zone is controlled by recording and controlling pyrometers similarly operated.

With this arrangement the temperature rise of the shell with time can be closely controlled. It is usually desirable to subject the cold steel to a slow initial heat in order to avoid thermal shock. In the second zone the heat is brought up to quenching temperature, and in the final zone the shells are uniformly soaked.

The furnace is heavily constructed, having a 9-in. firebrick lining, backed with $4\frac{1}{2}$ in. of 1600° insulating brick. The furnace shell is built of welded plate, reinforced with steel structural shapes and cast iron fronts. The cast iron door at the far or discharge end is lined with insulating refractories, and counterbalanced for manual operation to provide for inspection. Air for combustion is supplied at 1 lb. pressure by turbo-blowers.

As high explosive shells are all heat treated in rough machined condition, surface protection is a minor problem. It is, however, desirable to hold scaling and decarburization to a minimum. The atmosphere is accordingly controlled by adjusting the gas-air proportioning valves to give the desired "reducing" atmosphere, and normally the atmosphere is maintained slightly on the reducing side, to hold scale at a minimum. As the shells are exposed to temperatures at which decarburization can take place for only a relatively short time, very little decarburization occurs.

The Quench Tank

As shown in the drawing, Fig. 2, shells are discharged by alloy tubular chutes through the furnace floor directly into individual quench cages or baskets. The discharge tubes are water jacketed between furnace bottom and oil level, which prevents heat from traveling down the tubes and igniting the oil.

Since quenching the shells is a fundamental step that must be quick and proper, the cages are designed with internal jet tubes through which oil, at the proper temperature, is constantly pumped at a pressure of approximately 30 to 35 psi. This gives a thorough, internal flush. Just previous to this, oil at the same temperature and pressure enters in jets around the circumference of the discharge tube, just below the water jacketed section, giving the shells an external spray as they pass from furnace to the quenching basket.

After this initial external and internal flush quenching, the cages rotate 180° and the six shells drop out onto six parallel pusher conveyors which send each one through the tank, up and out, finally discharging on the draw furnace's conveyor. Shells come out of the quench tank butt first, allowing the oil to drain. The turnover mechanism in the quench tank is operated hydraulically by an oil cylinder, chain and sprocket. It is synchronized with the con-

Fig. 3 — Quench Tank (Drained of Oil) With Shells Occupying Positions in Quenching Cages and in Elevator-Conveyor. Note turnover mechanism at left of tank



veyor to provide proper spacing of the shells in the elevator flights. The entire layout is clearly shown in Fig. 3, photographed when the tank was drained of oil, and with shells occupying all positions in quenching baskets and conveyor flights.

The quench tank conveyor is driven by a standard motor, operating through a speed reducer and variable speed pulley. Operation of the pusher on the hardening furnace, which feeds the shells to the unit, is synchronized with the turnover mechanism and quench tank conveyor so that the entire cycle is controlled by the variable speed drive on this quench tank conveyor.

The size of the quenching tank and its capacity vary with the size and number of shells being heat treated, but about one gallon

chute to a conveyor belt and are then carried into the recirculating air draw furnace.

The Air Draw Furnace

The heating cycle of the draw furnace shown in Fig. 4 can be controlled independently of the hardening and quenching cycle, since the conveyor belt is driven by a separate motor through a speed reducer and variable speed pulley. This belt is 1-in. mesh, made of 10 gage, high carbon steel wire, with reinforcement rods $\frac{7}{16}$ -in. diameter of S.A.E. 5140 steel on $1\frac{1}{2}$ -in. centers. (See Fig. 5.) Five to nine chains with wear shoes carry the main belt load on supporting rails through its length.

Two fan systems, each with individual combustion chamber, provide better than 50 changes

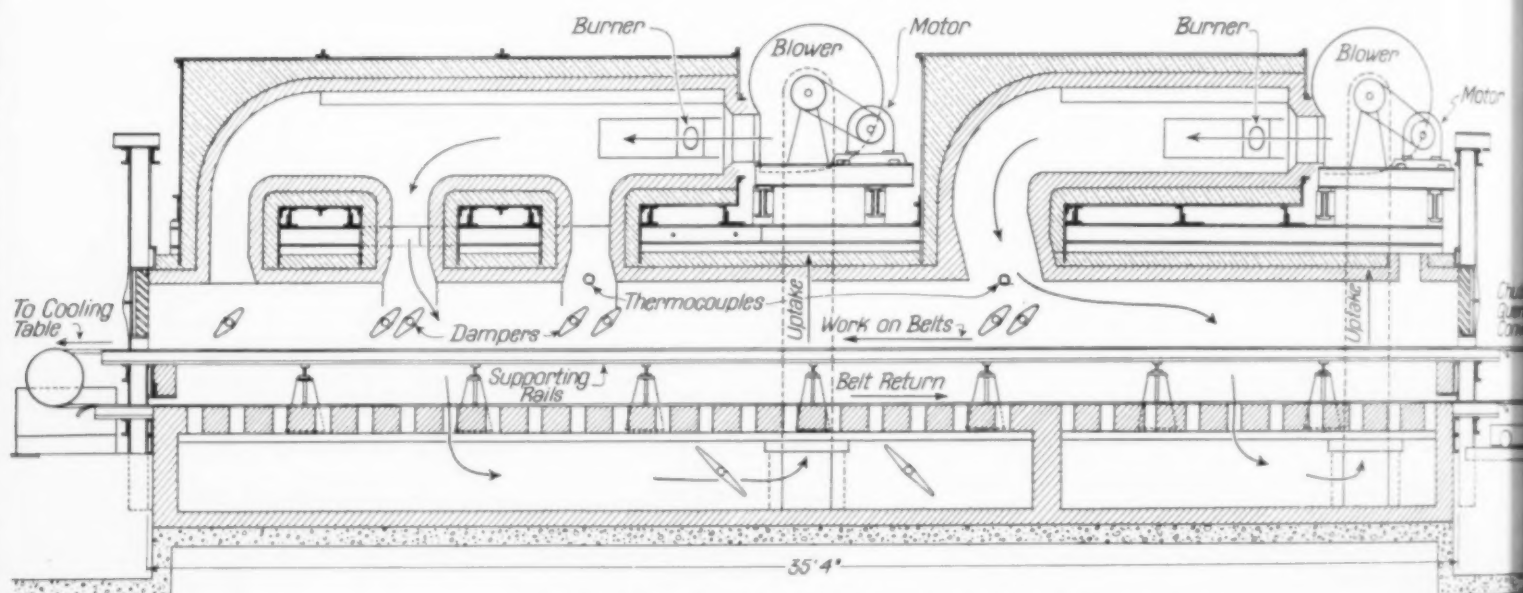


Fig. 4 — Cross Section Along Centerline of Air Draw Furnace

of tank capacity is allowed per pound of steel being quenched per hour. Six changes of oil per hour are usually allowed to assure uniform temperature.

Correct oil temperature is maintained by a separate cooling unit which receives the hot oil from the quench tank, cools it to a predetermined temperature, and recirculates it back to the quench tank, where it enters at the jets for internal and external quenching of the shell. The tank itself is built of heavy welded steel plate with structural steel reinforcement and with a structural steel conveyor frame, placed in a pit so its top is at floor level.

Discharging from the quench tank elevating conveyor, the shells slide down the discharge

of the hot air every minute. Fan impellers and housings are constructed of heat resisting alloys; impellers are mounted on special air cooled shafts and bearings, and powered by standard motors with V-belt drives.

Hot air enters the furnaces from ducts spaced along the top of the furnace arch. It then circulates downward and returns to the fans through ducts in the bottom of the furnace leading to side manifolds or uptakes. Control of the circulating air is maintained by dampers placed directly beneath the inlets, and in the return ducts.

Correct temperature is maintained by heat added from the combustion chambers which discharge hot gases of combustion into

the recirculating system at the fan discharge. Either oil or gas fuel is used with open type gas burners or double atomizing oil burners. Air is supplied at one pound pressure by turbo-blowers to provide proper pressure in the combustion chamber. An equivalent amount of spent atmosphere blows out of the system through front and rear openings and a roof vent near the front door.

Safety equipment consists of standard air flow switches and fuel safety shut-off valves, and flame guards for gas operation. Pilot burners with spark ignition are synchronized with the safety equipment so that lighting up is accomplished by merely pressing the control buttons. The draw furnace proper has a standard, heavy duty, welded plate shell reinforced with structural steel shapes, lined with $4\frac{1}{2}$ -in. firebrick for maximum resistance to air leakage, backed with $2\frac{1}{2}$ in. of 1600° brick, and 1 in. of insulating blocks.

The Cooling Chamber

After the shells have passed through the drawing cycle, they are passed along into the cooling chamber, in order to bring them down slowly to a temperature (150 to 175° F.) at which they can be handled without delay or difficulty. Handling is done by a heavy con-

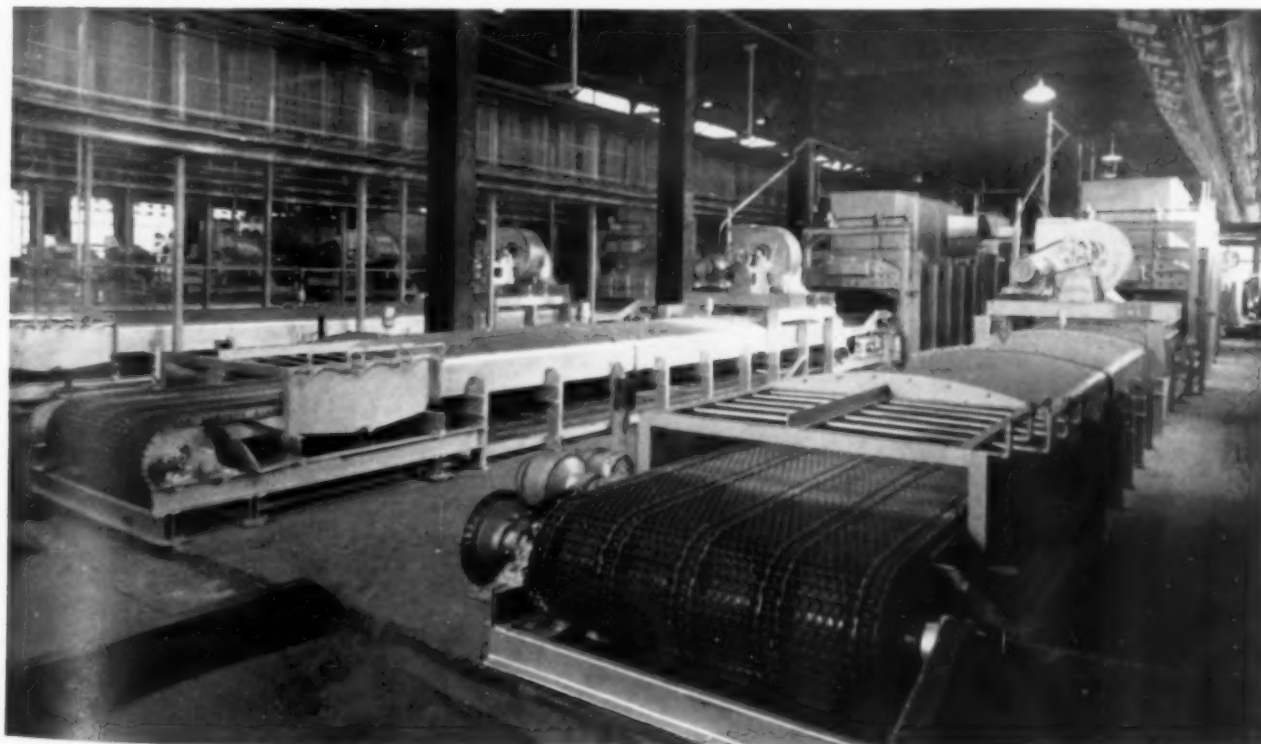
veyor belt, shown in Fig. 5, similar in construction, drive and operation to the draw furnace belt. This conveyor is surrounded with a water jacket for most of its length, and there is a large fan at the entrance end to draw cold air from the discharge end through the chamber. The water jacket is made in sections to minimize the effect of expansion and contraction. A short section of controllable water sprays, approximately four to six feet, completes the cooling.

On discharging from the cooling chamber the shells are checked for hardness and are ready for final machining.

A considerable amount of work has been done to determine the proper heat treating temperatures and cycles for the different shells, as they vary not only in size (diameter) and shape (purpose), but also as to incidental variations in steel analysis and forging heats. Since the wall thickness in each size differs, due allowance has to be made in the time-temperature cycle required for hardening and drawing. This is best determined by preliminary tests on the different lots of steel. Typical results as compared with the required Government specifications are as follows:

	TEST No. 1	TEST No. 2	SPECIFIED
Elongation	26.5%	26.0%	15.0% min.
Reduction of area	58.1%	54.7%	35.0% min.
Yield strength	70,500 psi.	72,750 psi.	65,000 psi. min.

Fig. 5 — Cooling Tables on a Battery of Seven Shell Treating Units



Proper Microstructure

The importance of temperature and time in the hardening furnace when heat treating high explosive shells is apparent from various metallurgical studies. Temperature must be sufficiently high and the time sufficiently long to insure complete solution of the carbides and to recrystallize the austenitic grain. Under the present war pressure some shell forgings are being produced at a rather high forging heat. The result is a very coarse grain structure. To obtain the proper results on such forgings requires a higher hardening temperature than ordinarily considered necessary.

The photomicrograph at the left of Fig. 6 shows typical grain structure of the shell forgings. The center micro shows shells improperly heat treated, and hardened from just below the upper critical point. The lack of complete solution of the original ferrite network is clearly evident. The photomicrograph at the right is a properly heat treated shell, with hardening temperature well above the upper critical point. Actually there was a difference of only 30° F. between the hardening temperature of the two, which shows the importance and critical nature of the correct hardening temperature.


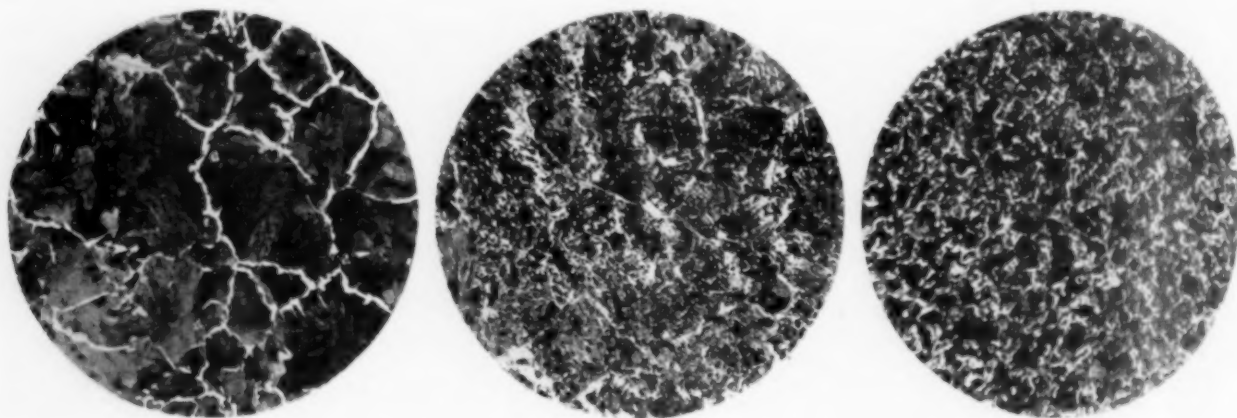
Experience has very definitely indicated that the automatic four-cycle installation (harden, quench, draw, and cool) completely refines the grain structure of these shells, when due allowance is made in time and temperature for the microstructure, grain size and composition of the original forgings. 

Fig. 6 — Photomicrographs of High Explosive Shells. Left, forging finished at a rather high heat. Center, quenched from too low a temperature. Right, properly heat treated. All samples polished, etched with nital, and photographed at 100 diameters



Reclaiming Values From Bullet-Jacket Scrap

REPORT No. 1 from the War Metallurgy Committee of the National Academy of Sciences on the reclamation of copper, zinc and steel from scrap bullet jackets has been released for publication. It will be recalled that this committee was organized to supervise research on problems arising in the War Production Board and connected with the more efficient use of strategic metals. The necessity of the work arose from the decision of the Ordnance Department to use clad steel for bullet jackets rather than a jacket of solid "gilding metal" (90% copper, 10% zinc). The clad steel so used, being four-fifths steel and one-fifth brass, will save 80% of the required non-ferrous metal. Scrap from rolling mill operation, punch press webbing, and cup forming will amount to about 20,000 tons monthly by mid-1943. The report on its reclamation is briefed below.

At the request of representatives of the War Production Board, several industrial concerns have considered recovery methods on the gilded-steel scrap, and a variety of processes which showed promise have been tried. None of the other processes which were considered have been developed past an experimental stage, and none of them showed any worthwhile advantages over the cupric ammonium carbonate leaching method.

There are three known companies who have had experience with the leaching of gilded steel by the cupric ammonium carbonate method — Calumet & Hecla Consolidated Copper Co. at Lake Linden, Mich., American Metal (Cont. on page 916)

Bits and Pieces

What is "Decarb"?

Now that we have on record in this and the September issue of this journal no less than five methods (plus one variation) for measuring case depth, the same doubt arises about the word "decarburization". What does this mean? Rather I ask, "What *should* it mean?" Recently I saw a report mentioning "total decarb" and "totally decarburized"! METALLURGICUS

Carburizing Test on NE8620 and 8817

PRIOR to a recent meeting to tell engineers in the San Francisco region about the national emergency steels, two samples of the new steels (kindly furnished by the Republic Steel Corp. Massillon laboratory) were carburized and compared with pieces of more familiar steels. This work was done by R. R. COLE of the Metallurgical Laboratory of Hall-Scott Motor Car Co. in Berkeley. Report and tabulation is below:

The 5½-in. long specimens were normalized at 1730° F., ground to 0.600 in. diameter, carburized at 1680° F., quenched in oil from the pot, reheated to the temperature shown in the table and again quenched in oil. They were then drawn 1¼ hr. at 300° F. Determinations were made on the heat treated specimens for out-of-straightness or run-out, hardness and case depth. The relative ductility of the case was determined by measuring the deflection at the center as the specimen was loaded in the middle

of a 4¼-in. span; maximum deflection was read when the case snapped. (GEORGE A. NELSON, Metallurgist, Shell Chemical Co.)

Removing Scale and Stain from Brass

FERRIC SULPHATE does an exceptionally good job in removing black smut and red cuprous oxide scale from brass. The advantage is the speedier removal of stains and scale, and the greater conservation of metal. By this method, for instance, the fine engraved design on brass buttons is preserved as well as metal itself.

Ferric sulphate is used for the same purpose in the manufacture of brass cartridge cases. Since this consists of a series of drawing and annealing operations, it is essential that all scale and stain be removed before each draw or there is a likelihood of fouling the drawing dies and scoring the work. (RALPH E. NELSON, Technical Service, Monsanto Chemical Co.)

Tool Hardener: Watch That Anneal!

WE HAVE OBSERVED that the annealing of toolsteel prior to hardening is usually left to the hardener's discretion, although it is most important in determining the microstructure and consequently the usefulness of the completed tool. To demonstrate this point we cut up a bar of manganese oil hardening toolsteel into necessary tensile specimens, and divided them into four lots. One lot was tested as

STEEL	CHEMICAL ANALYSIS								QUENCH	CASE DEPTH	HARDNESS		RUN-OUT	DEFLECTION
	C	Mn	S	P	Si	Ni	Cr	Mo			CASE	CORE		
A 2317	0.17	0.63	0.014	n.d.	n.d.	3.39	....	....	1385° F.	0.039 in.	C-63	C-41	0.0047 in.	0.075 in.
A 3115	0.14	n.d.	n.d.	n.d.	n.d.	1.42	0.56	....	1435	0.039	63	14	0.0019	0.075
A 4615	0.18	n.d.	n.d.	n.d.	n.d.	1.82	....	0.27	1460	0.047	65	32	0.0083	0.072
NE 8620	0.20	0.80	0.015	0.014	0.23	0.43	0.52	0.22	1500	0.042	65.5	30	0.0012	0.050
NE 8817	0.20	0.84	0.015	0.015	0.29	0.48	0.52	0.33	1500	0.042	65	43	0.0037	0.062

Effect of Prior Microstructure on Properties of Quenched and Drawn Toolsteel

PREVIOUS CONDITION	HARDENED, DRAWN AT 800° F.			HARDENED, DRAWN AT 1000° F.		
	ELASTIC STRENGTH	TOUGHNESS (a)	HARDNESS	ELASTIC STRENGTH	TOUGHNESS (a)	HARDNESS
Spheroidized	230,000	14,975	C-47.5	178,200	18,400	C-39.5
Air cooled	233,000	13,925	C-49	200,000	17,500	C-41.5
Furnace cooled	196,000	8,725	C-48	175,000	15,325	C-40.5
Box cooled	203,000	9,675	C-49	184,000	13,075	C-39.5

(a) Determined as "Energy of Rupture" in in.lb. per cu.in. from the formula

$$\frac{S_y + S_{max}}{2} \cdot \frac{\% \text{ Elongation}}{100}$$

where S_y is the stress in psi. at the yield point, and S_{max} , the ultimate strength

received (spheroidized condition). The other lots were annealed at 1450° F., one in a salt bath and air cooled, one in cast iron chips and furnace cooled, one in cast iron chips and box cooled in air. Subsequently samples were oil quenched from 1450° F., and drawn either at 800 or 1000° F. for 30 min. Results are shown above.

If strength is the most important feature desired, harden from the air cooled condition. For best combination of strength, toughness, and resistance to wear in the tool, the spheroidized condition is the correct structure prior to hardening. (THOMAS R. LEWIS and COLUMBUS VERDI, Picatinny Arsenal.)

Measurement of Case Depth★

In re METALLURGICUS' request for commercial methods of measuring case depth:

The slow cooled sample is prepared for microscopic examination and the depth to a half-and-half structure of pearlite and ferrite is taken as the case depth.

The reasons why we like this definition better than any other we have come across are:

1. It provides for any effect which the alloy may have on the eutectoid composition.
2. This depth corresponds to the depth at which the first ferrite grain occurs in a part quenched for case hardness only.
3. This depth corresponds to the depth at which approximately 5% troostite appears in the case and begins to reduce its hardness in a part quenched from above the upper critical. (ERNEST J. LUDERS, Assistant Metallurgist, John Deere Tractor Co.)

★EDITOR'S QUERY—By the way, does anyone use the simple old way? Break a piece after hardening, warm the fracture gently from the rear in a gas flame until "temper colors" just start to form. Measure the blue ring around the red core.

Separation of High Speed Steels by Spark Testing

IT IS VERY SIMPLE to separate the tungsten high speed steels from the molybdenum types. The former give long, lean, dull red spark streams with no carbon bursts at all. The sparks from the molybdenum high speeds are shorter but much more numerous, are orange red or straw in color with only traces of red near the wheel, and they end in well-defined spearpoints preceded by some sort of a burst due to carbon. (The condition of the steel, whether annealed or hardened, and the grinding conditions affect these spark streams considerably, although their general nature remains the same.)

The various molybdenum types can also be distinguished among themselves if standard specimens of known composition are available to check against. The 5:5 W:Mo type does not give off quite as many sparks as the 1.5:8.5 W:Mo or "Mo-Max" type. The latter also has a slightly more pronounced carbon burst and a longer spearpoint at the end of each spark. Addition of cobalt decreases the length of the spark stream but a very large number of distinctive carbon bursts appear. The spark stream of a straight molybdenum high speed is also short and intense, with very many carbon bursts, but these sparks can be easily distinguished from those given off by the cobalt-bearing type just mentioned. (L. P. TARASOV, Research Laboratories, Norton Company.)

"Bits & Pieces" (Metallurgicus' Own Page) is designed for small but useful notes on things that have troubled ASMEs and how to avoid them. Send in your own. The reward is any ☉ book (except the Handbook)

Short annealing cycles for improving machinability of difficult alloy steels are great time savers. Spheroidize annealing of 52100 is shown to depend on soaking at a temperature where some carbides are left undissolved and then cooling to a little below the critical for rapid transformation to spheroidite

Spheroidize Annealing of S.A.E 52100 Steel

S.A.E. 52100 STEEL is consumed, in the most part, by the bearing industry where it is used for bearings and bearing race rings. Steel for this application is made in the electric furnace, where control is kept at the optimum to assure a high quality product. Ingots are rolled to bars, pierced into tubes, and heat treated to the customers' specifications—usually as “spheroidize annealed”. This anneal necessitates close control if mill rejects are to be kept at a minimum. The many problems that confront the metallurgist and heat treater can readily be understood when the size of furnace and tonnage output of the mill are taken into consideration.

The consumer demands a fully spheroidized structure free from elongated carbides and pearlite. Spheroid size is sometimes specified within definite limits, inasmuch as non-uniformity of carbide shape and size affects the quality of the machined surface. It is also desirable that the spheroids be not too large, as the particle size apparently affects the rate at which carbides go into solution in the hardening heat.

It has been only in the last few years that the structure sometimes called “spheroidite” has been recognized as a direct transformation product of austenite. The former opinion has generally been that during a spheroidizing anneal, lamellar pearlite forms first from austenite at temperatures not far below the critical, and that the cementite plates of the pearlite

later break up or “divorce”, to form spheroids of carbide. PETER PAYSON, W. L. HODAPP and J. LEEDER in their most excellent paper entitled *The Spheroidizing of Steel by Isothermal Transformation* (*Transactions, American Society for Metals*, Vol. 28, June 1940) proved conclusively that under certain conditions spheroidite formed directly from austenite. It appears that a successful spheroidizing anneal depends on keeping the top annealing temperature, in the case of hyper-eutectoid steels, below the A_{cm} line. Should the annealing temperature be above the A_{cm} line and conditions such that the steel would be composed of *entirely uniform austenite*, the austenite on slow cooling would, no doubt, transform into pearlite, as demonstrated by Dr. MEHL in the Campbell Memorial Lecture (1911).

For the sake of simplicity and ease of expression the phrase “austenitizing temperature”, and the word “austenitized” are used by PAYSON and his associates, as well as by the present author, quite frequently (and perhaps erroneously) for in no case did my S.A.E. 52100 steel consist entirely of austenite when heated to temperatures above the critical. The structure of the steel, at all temperatures studied above

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Chief Metallurgist
Firestone Steel Products
Fall River, Mass.

Fig. 1 to 4 — Specimens of S.A.E. 52100 Heated 1 Hr. at 1430°F., Quenched in Lead Baths at Temperatures Noted, Held 2 Hr. for Isothermal Transformation, and Quenched in Water. Pical etch; magnification 2500 diameters. No pearlite appears at 1275°F. or above

the critical, was composed of austenite and undissolved carbides.

In the present instance the S.A.E. 52100 steel was investigated isothermally to determine, under a definite set of conditions, the level at which austenite would cease transforming to spheroidite and begin to form pearlite, and to note the effect of the austenitizing temperature on the structure obtained by constant temperature transformations. A study was also made to obtain data on the formation of spheroidite during a furnace cool.

The isothermal studies were made in the conventional manner. Small specimens $\frac{1}{8}$ by $\frac{1}{8}$ by $\frac{3}{8}$ in. were austenitized for one hour, then transferred to a lead bath maintained at the particular temperature level under investigation. The analysis of the steel is as follows:

C	Mn	P	S	Si	Ni	Cr
1.04	0.45	0.013	0.008	0.34	0.13	1.44

Specimens were austenitized at 1430 and 1500° F. and quenched into lead maintained at temperatures of 1360, 1340, 1320, 1275, and 1260° F. These specimens were finally quenched into water after remaining in the bath for two hours. No attempt was made to establish the beginning and ending of transformation, as in S-curve studies. It was found, as shown in Fig. 1 to 3, that the steel austenitized (heated and soaked) at 1430° F. transformed directly into spheroidite at temperatures of 1275 to 1340° F. At 1360° F. no transformation was evident after two hours at temperature. This is not surprising, as this temperature is about 5° above the 1355° F. critical determined for this specific analysis. (Any mention made to "critical", in this article, refers to the temperature at which austenite begins to form when the steel is heated.) Figure 4 is representative of specimens austenitized at 1430 and quenched into a lead bath at 1260° F.; close examination reveals pearlite. Evidently, in specimens austenitized at 1430° F. and transformed isothermally, pearlite makes its appearance somewhere between 1275 and 1260° F.

It can readily be recognized from the photomicrographs that the size of the spheroids is the same at all temperature levels investigated. Obviously then, the size of the cementite spher-

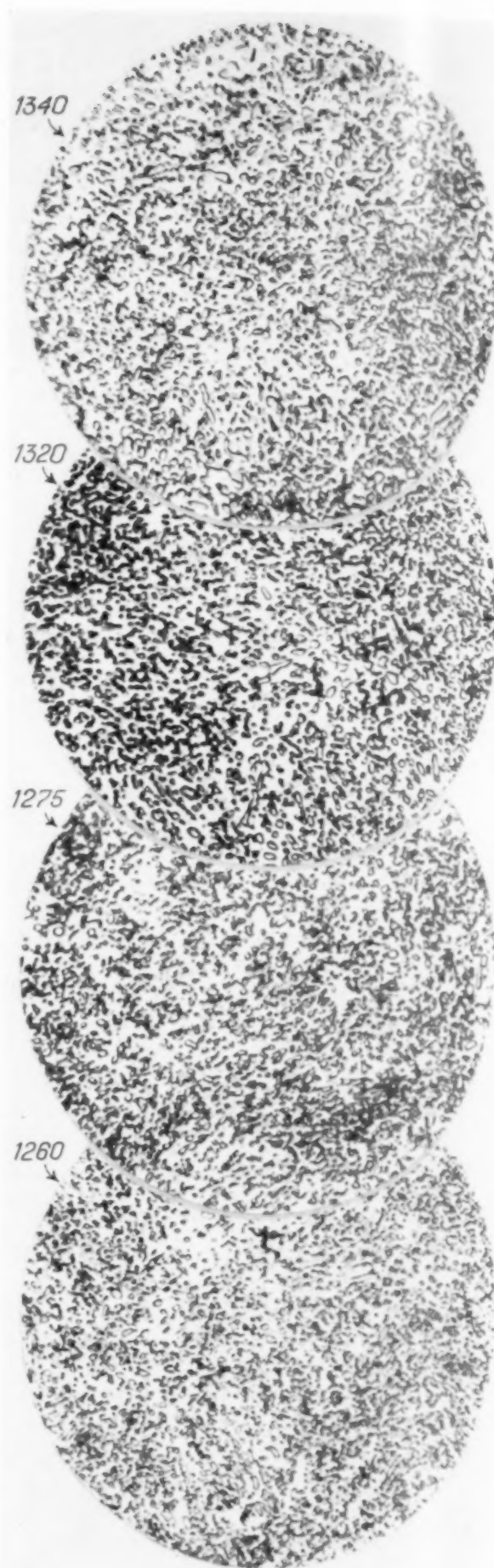




Fig. 5 — S.A.E. 52100 Annealed 1 Hr. at 1500°F., Transformed 2 Hr. at 1320°F. Note appearance of pearlite, undesirable for best machinability. Magnification 2500 diameters

roids cannot be controlled by the temperature of formation. It can be controlled by the time at these temperatures, as will be explained later. Considering the high magnification, it is interesting to note the extreme fineness of the cementite spheroids; hardness was low, as required for machinability.

Fig. 7 — Structure of Steel "Austenitized" 1 Hr. at 1430°F. (Below A_{cm}) and Water Quenched. Note remaining undissolved carbides. Picral etch; magnified 2500 diameters; hardness C-65



Steel that is spheroidize annealed and examined for microstructure is often found to be composed of spheroidite and varying percentages of pearlite. Sometimes the appearance of pearlite in a structure that should be 100% spheroidite is blamed on too rapid a rate of cool. Figure 5 is a photomicrograph showing the presence of the undesirable constituent pearlite. This specimen was austenitized at 1500 and transformed at 1320° F. The structure of the S.A.E. 52100 specimen so treated consisted of spheroidite plus pearlite. The specimen of Fig. 2 was also transformed at 1320° F., but was austenitized at 1430° F. (close to the mill annealing temperature) and no pearlite appears in its structure. There seems then to be a definite relationship between the austenitizing temperature, and the temperature below the critical at which pearlite will begin to form.

It may generally be stated that as the austenitizing temperature increases the tempera-

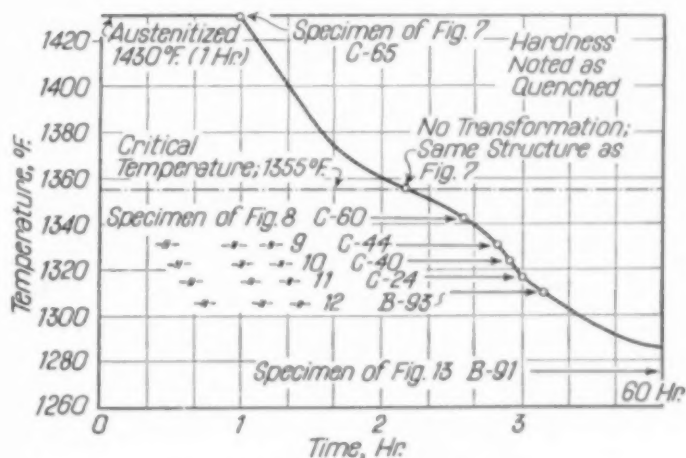


Fig. 6 — Time-Temperature Cycle for Samples Transformed During a Slow Furnace Cool

ture at which pearlite is formed also increases and approaches the critical. It follows that as the austenitizing temperature is increased, within limits, the rate of cooling must be decreased for a 100% spheroid structure. In the spheroidizing anneal the most important single factor is the selection of a minimum austenitizing temperature — better described as the lowest temperature for any steel at which the steel will consist of austenite and non-lamellar carbides. Although a heating and soaking temperature of 1500° F. was instrumental in causing pearlite to form at 1320° F. in these experiments, it is actually used as the austenitizing temperature in some mill anneals, perhaps for the reason that the very slow cooling of large

Fig. 8 to 13 — Progress of Transformation During Furnace Cooling Below Critical. Lighter areas were untransformed austenite (martensite in quenched steel). Quenching temperature and resulting hardness as noted

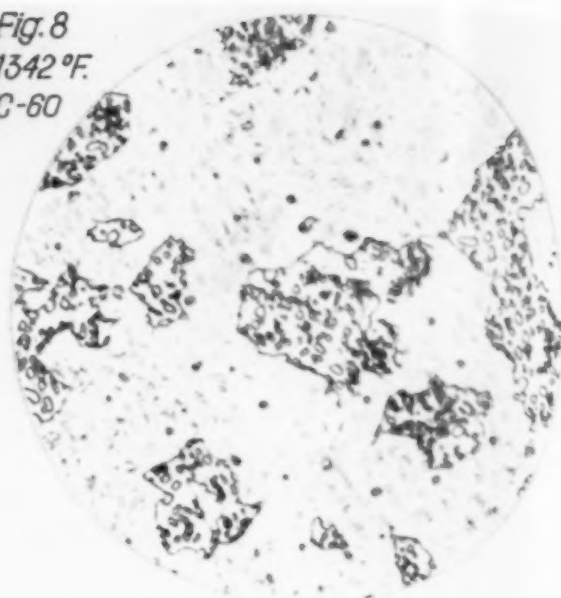
masses of metal, at about 10° F. per hr., results in a transformation to spheroidite just below the critical — certainly above 1320° F.

The application of the principles just described is believed to be of little practical importance as applied to the heat treating cycles for large batch-type furnaces now in use in many steel mills. However, by taking advantage of the isothermal behavior of S.A.E. 52100, the structure spheroidite could be produced very economically in a continuous type furnace with two or more zones operating independently of each other. The steel to be spheroidized would enter the furnace and pass through a zone where it would be heated for a long enough time and at a temperature, perhaps 1435° F., that would give a structure of austenite and undissolved carbide; the steel would then pass through a cooling section into the next zone or zones maintained at the isothermal temperature where the transformation of austenite to spheroidite would take place. A continuous operation such as the one just described should prove to be very practical and would require only a fraction of the 30 hr. now required for spheroidize annealing in large batches.

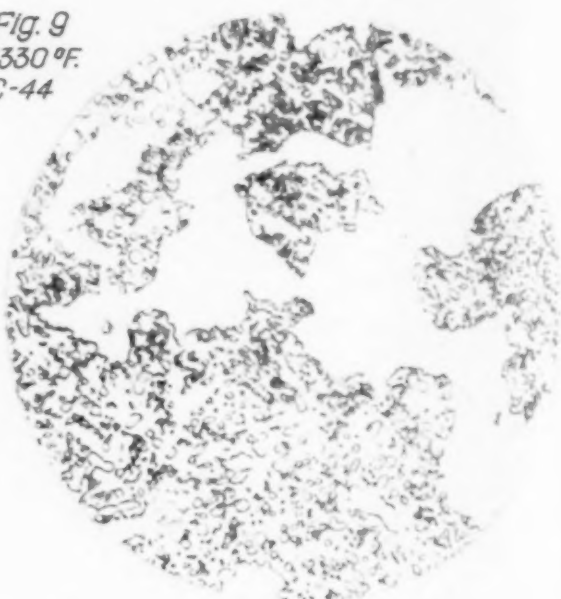
We next investigated the formation of spheroidite during a furnace cool, both to substantiate the isothermal data and to clarify the mechanism of the spheroidizing anneal. Actually the effect of slow cooling large quantities of metal is to give ample time at slightly sub-critical temperatures for the same transformation to take place that was described in the first part of the paper, and also to equalize temperature throughout the large charge.

In studying the transformation of austenite to spheroidite when specimens of the S.A.E. 52100 were furnace cooled, a similar procedure to that used in the isothermal transformations was adopted. To facilitate handling of the small specimens, a wire was attached to each, reaching out through the thermocouple hole in the door; thus it was possible to remove the specimens at will without opening furnace door and destroying the cooling cycle. Specimens were removed at various temperatures during the cool and quenched into water. Any untransformed austenite that existed in the specimen at the time of its removal would appear in the

*Fig. 8
1342°F.
C-60*



*Fig. 9
1330°F.
C-44*



*Fig. 10
1325°F.
C-40*

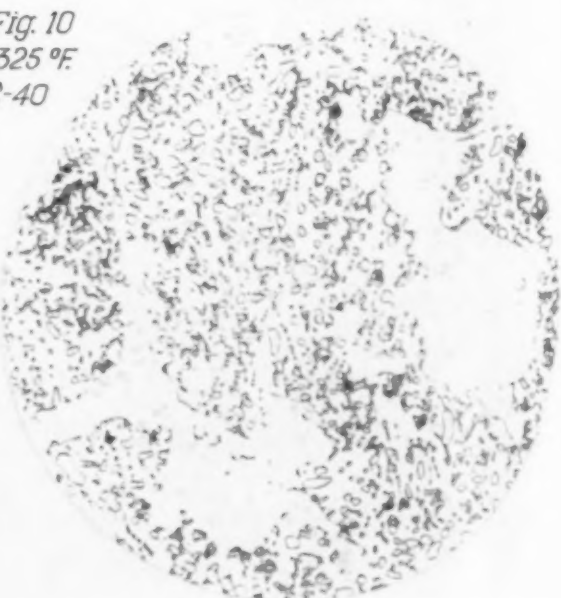


Fig. 11
1316 °F.
G-24

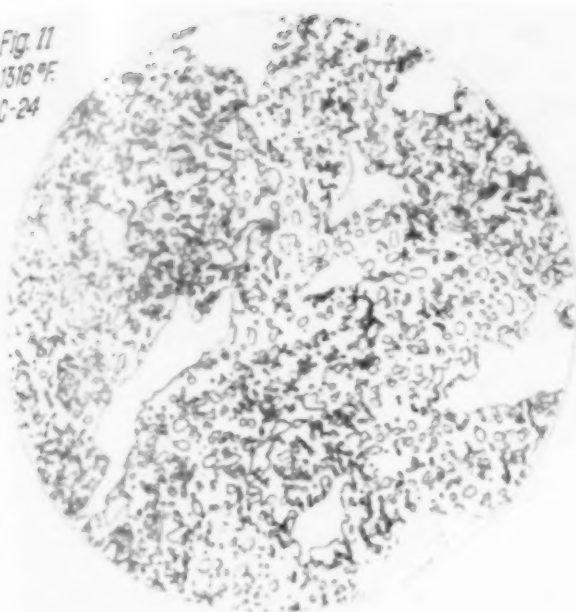


Fig. 12
1310 °F.
E-93

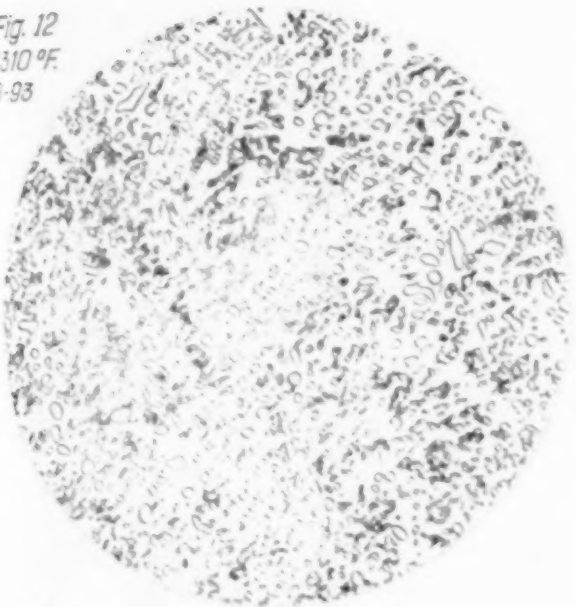
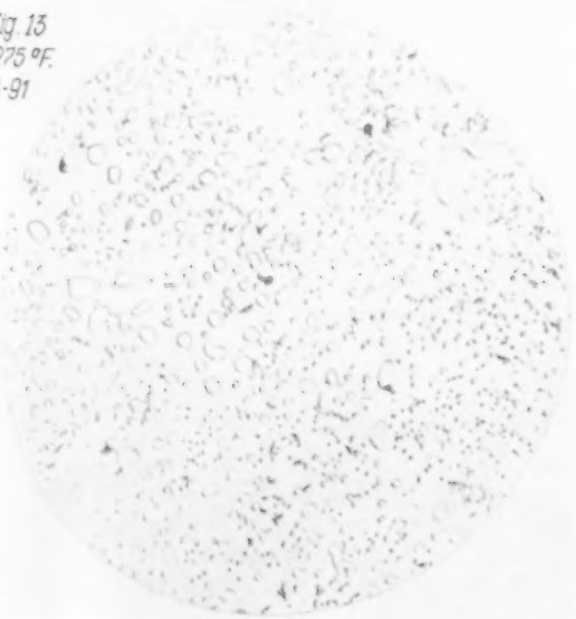


Fig. 13
1275 °F.
B-91



polished specimen as martensite, and the progress of the transformation of austenite to spheroidite could be closely followed.

Specimens were austenitized at 1430° F. for one hour. Time-temperature curve during cooling is shown in Fig. 6. A complete picture of the transformation is shown in Fig. 8 to 13. Transformation to spheroidite begins quite rapidly at 1342° F., soon after passing the critical, and ends 35 min. later at a temperature of 1310° F. Fig. 7 shows the structure of a specimen austenitized at 1430° F. for one hour and quenched into water. Although it appears that much carbide is undissolved, the austenite was of a high enough carbon content to give a hardness of Rockwell C-65 when water quenched.

As stated earlier in this paper, the size of the cementite spheroids obtained by furnace cooling and isothermal transformation was many times smaller than the spheroids of the structure generally accepted by the consumer of bearing steels. Figure 13 shows a specimen that received the same cool as the other specimens but was not removed until it had remained 60 hr. at 1275° F. This additional time of holding resulted in coalescence to larger spheroids. Another point then that must be considered is that the size of the cementite spheroids depends on the time the steel is held below the critical. It may be stated that the slower the rate of cool the larger will be the spheroids of cementite.

It was believed worthwhile to determine if the rate of cool from the austenitizing temperature to the critical had any pronounced effect on the structure of the transformation product. Experiments indicated that the rate of cool from austenitizing temperature to critical did not influence the structure formed below the critical.

This article tends to substantiate the fact that spheroidite, under a definite set of conditions, forms directly from austenite. A structure of spheroids of carbide and ferrite is usually associated with a very slow anneal. Actually austenite transforms to spheroidite quite rapidly. In the case of the furnace cooled specimens described in this article, a structure consisting entirely of spheroidite was produced in one hour after the steel passed the critical. Of course, the large furnace charges must be annealed slowly to avoid large variations in temperature between parts of the massive charge and furnace; nevertheless, it is quite possible that even here the time can be reduced by studying all the conditions that influence the decomposition of austenite. ☺

Since no copper producer was willing officially to discuss the copper situation, The Editor urged War Production Board to make a statement which could be included in the October issue. Here is the belated document, written more for the populace than for the technician

Supply and Demand for Copper

CURRENT copper supply, in excess of 200,000 tons per month, is the largest in the country's history. Domestic mine and smelter production is larger than ever before, imports exceed any previous year, and scrap collections are at a new high. (Approximately 31% of this year's total copper supply will come from old and reprocessed mill scrap.)

However, the extreme tightness of the copper situation is demonstrated by the fact that copper currently used for domestic electric systems, communications, industrial motors and fittings, chemical plants and all of the thousands of industrial and essential civilian purposes which must be met, is much less than one-fifth of our total supply. Copper scarcity is further reflected by the recent announcement that even brass and wire mills and foundries would be allotted no copper of any kind, including scrap, except on preference ratings of A-1-a and higher.

To meet this unprecedented demand for copper, domestic production this year is more than twice 1938 production (a lower-than-average year), and imports are greater than ever before. The following figures show how the copper industry has responded to war needs, beginning with exports for military purposes to Europe in 1939. The totals include domestic production, scrap and imports.

United States Copper Supply

1939	1,525,500 short tons
1940	1,913,800
1941	2,467,100
1942	2,571,700 (estimate)

For decades the United States has been the largest producer, and the largest consumer, of

copper. Despite our overwhelming superiority in copper production, we have recently leaned heavily on imports. The last year for which complete figures are available, 1938, shows how we stood with respect to the rest of the world:

Smelter Production (Exclusive of Scrap)

United States	570,773 metric tons
Canada	215,732
Chile	337,508
Germany	70,000
Russia	114,552
Yugoslavia	41,993
Japan	102,000
Africa	353,861
Australia	17,372
Other countries	217,209

Total 2,041,000 metric tons

With United States copper supply this year greater than the whole world's in 1938, it is clear that, badly as we need copper, we still are far out in front of the Axis powers.

Steel is being substituted for brass in some ammunition today in an attempt to take some of the pressure off copper. Steel is short, but copper is relatively shorter. Copper is non-replaceable for many essential military purposes, and in view of the limited supply of copper, some other critical materials must be substituted for it when possible. There is just one reason why we must have nearly five times as much copper this year as our mines produced in 1938. That reason can be found by examin-

By H. O. King
Chief, Copper Branch
War Production Board

ing the material being used to fight this war. A medium tank takes almost a half ton of copper; one type of scout car, 150 lb. One type of fighter plane uses over 800 lb., and the Flying Fortress uses over a ton and a half. All these are front-line fighting tools. We must have them in great quantities, and they cannot be built without copper. That is where our copper is going.

One type of bomber uses 500 lb.; a front-line battleship uses 2,000,000 lb. The copper that normally would go into electric refrigerators, which are not being made this year, will provide the copper and brass to complete 60 destroyers. Ammunition is the largest user of copper. The casing on every round of ammunition from a 0.30-caliber bullet to a big 105-mm. shell is made of cartridge brass — 30% zinc and 70% copper. Modern warfare burns up ammunition at a rate never before dreamed of. In the battle of Britain, in 1940, aviation experts were astounded at the amount of ammunition consumed per hour.

The copper situation can be summed up with the statement that it is quite possible that copper supply will determine the amount of munitions and war material that we can produce in some of the major categories. Estimated *essential* requirements for 1942 are over 8% in excess of maximum present visible supply; estimated *total* requirements for 1942 are some 25% in excess of present visible supply.

What Can We Do About More Copper? — Our attack on the critical copper situation has several spearheads. First of all, we have increased production tremendously — more than doubled it since 1938, in fact. Then too, we are importing as much as we can. Two other war measures are first the severe restriction of non-essential uses, and second the substitution of other materials for copper wherever possible.

Production is being increased by intensified effort in well-established mines, and by bringing into production the sub-marginal mines whose operation in peacetime had not been economic. The large producers (15 companies produce 98½% of our copper) are working their properties as hard as the labor shortage will allow — some are working 168 hr. a week. To encourage fullest production in normally unprofitable mines, a bonus system has been worked out by the Metals Reserve Co., a sub-

sidary of the Reconstruction Finance Corp., to pay the premium price of 17¢ per lb. for all production over a certain quota. This contrasts with current open market price of 12¢. Altogether, the Government is spending over \$180,000,000 and private industry more than \$40,000,000 to develop new copper-producing facilities.

Labor shortage continues to be one of the major problems facing copper producers. Current production actually is being cut by manpower shortage, an estimated 5000 tons of copper having been chopped off July output by labor shortage in mines and smelters.

From Overseas — Imports are playing a big part in our copper supply. We will receive larger amounts than ever from some of our Good Neighbors to the south, principally Chile, Peru and Mexico, and from Africa and Canada.

What About Non-Military Uses? — Some non-military uses of copper are essential and must be continued. Light and power for industry and housing must be provided, communications must be maintained, and a few other uses without which our society could not operate are being taken care of in a limited way. Aside from these, you could not legally buy a pound of copper with an equal weight of gold! Restrictions on copper use for non-essentials are such that no copper may be used without specific authorization of the War Production Board.

Substitutions — Many ways are being found to substitute other materials for critical copper. Revisions of brass specifications are being made even in Army and Navy munitions to conserve copper, and other switches to less critical metals

*Converter Copper Being Cast Into Anodes for Electrolytic Refining.
Photo by Wide World at Washoe Smelter, Anaconda, Mont.*



are being made wherever possible. Steel is being used in shell casings instead of brass. Simplification of pipe fittings saves enough copper in a year to put the rotating bands on a million 14-in. projectiles.

Substitution of silver for copper in electrical conductors, during the last few months, has saved 12,000 tons of prime copper, according to estimates prepared by Harvey A. Anderson, chief of the conservation and substitution branch. This has been made largely in bus bars (large slab-like conductors leading current into electrolytic cells) in 10 war plants being constructed to make magnesium, aluminum, graphite and synthetic phenol.

A minimum of 34,000 tons of silver has been allotted to the Defense Plant Corp. by the United States Treasury and must be returned after the war. The Defense Plant Corp., in turn, is lending this silver to those plants that must have large quantities for operation, that can conveniently protect the silver, and that are in operation almost constantly. The silver is made available with the stipulation that it can be used only for a non-consuming purpose.

Silver actually is a better conductor of electricity than copper; is easy to cast and roll, and is not a critical material. The amount of copper that it has replaced thus far is an appreciable percentage of total domestic copper production, and additional use of similar substitution can be expected.

The saving so far represents enough copper to make 95,000,000 aircraft machine gun cartridges, plus 600,000 anti-tank shells, plus 1,500,000 anti-aircraft shells.

Our Last Resort — A vast mine of copper exists in this country, the obtaining of which can be speeded by every American. That mine is unused scrap and waste copper. By collecting old scrap and channeling it back into production, we hope to make available this year an additional 300,000 to 400,000 tons of copper.

One part of this program is the activity of Copper Recovery Corp., which acts as an agent of Metals Reserve Co. in buying up stocks of unused copper and brass, and even fabricated products made of these metals, which are not being used in essential war work. This agency will serve to direct such unused stocks into the hands of those who need copper, thus avoiding the continued existence of idle inventories. Collection and resale of this inventory copper and copper alloy are running as high as 5,000,000 lb. per week, on a purely voluntary basis. ☼

Saving Tin on Cans

W.P.B. Official Release

■ THIS YEAR'S domestic wartime demand for tin for cans, over 21,000 long tons in 1942, will be cut almost in half in 1943 by a program now under way to use electrolytic tin plate and bonderized black plate in place of hot dipped tin plate. Peacetime practice was to make cans from hot dipped tin plate having 1.5 lb. of tin per base box of about 100 lb. Under pressure of wartime conservation, hot dipped plate was early reduced to 1.25 lb. of tin per base box where such plate is applicable. Realizing that this reduction was only a drop in the bucket in a situation where 90% of our tin supply had been cut off, the steel industry has gone into production of a new type of tin plate requiring much less tin — electrolytic plate.

Electrolytic tin plate had been in limited use for several years, mostly for dry-packed products. The production process is a deposit of pure tin on steel black plate by electrolysis, similar to nickel or chromium plating. Experience has proved that electrolytic tin plate can be made with as little tin as 0.1 lb. per base box, one-fifteenth that in old-fashioned hot dipped plate. A tin deposit of 0.5 lb. per base box is, however, more practical for most purposes, and it is on this basis that most of our new electrolytic tin plate is being made.

A second important source of metals for cans, at the same time reducing the amount of tin required, is bonderized black plate. This is a process of treating the surface of the steel so that certain lacquers will adhere to it firmly enough to prevent corrosion by the substance packed.

The kind of plate required in cans varies with the substance to be packed, and this problem has been given careful study by a sub-committee on Conservation of Tin in the Food-Canning Industry, appointed by the Advisory Board to WPB on Metals & Minerals. Some products (principally acid fruits) probably need the 1.5-lb. coating, but only 5% of the tin cans made must be of this type. At the other extreme, some foods can be packed satisfactorily in steel plate without any tin at all.

To bring about maximum conservation of our limited tin supplies in fulfilling the needs for which tin cans *must* be used, the War Production Board has under way a program of progressive decrease of tin in cans.

The first step in conservation, already accomplished, is limitation on can use. (Cont. on p. 914)

A.I.S.I. Standard Steel Compositions

Revised Sept. 22, 1942

CODE FOR PREFIXES:

A is basic openhearth alloy steel.
B is acid openhearth carbon steel.
C is basic openhearth carbon steel.
E is electric furnace steel.

NE is National Emergency standard steel; designation promulgated by W.P.B.
Q is forging quality, or special requirement quality.
R is re-rolling quality billets.

Basic Openhearth and Acid Bessemer Carbon Steels

ATIS Number	Semi-Finish	Bars	Wire Rods	C	Mn	P (b)	S (b)	'42 SAE Number
C 1005	Q, R	✓	✓	0.04 max.	0.25 max.	0.04	0.05	1005
C 1006	Q, R	✓	✓	0.04 max.	0.25-0.40	0.04	0.05	1006
C 1008	Q, R	✓	✓	0.10 max.	0.30-0.50	0.04	0.05	1008
CB 1008	Q, R	✓	✓	0.07-0.13	0.25-0.40	0.04	0.05	1010
C 1009	Q, R	✓	✓	0.08-0.13	0.30-0.50	0.04	0.05	1010
C 1010	Q, R	✓	✓	0.10-0.15	0.30-0.50	0.04	0.05	1010
C 1012	Q, R	✓	✓	0.15 max.	0.60-0.90	0.04	0.05	1015
CB 1012	Q, R	✓	✓	0.11-0.16	0.60-0.90	0.04	0.05	1015
C 1013	Q, R	✓	✓	0.13-0.18	0.60-0.90	0.04	0.05	1015
C 1014	Q, R	✓	✓	0.13-0.18	0.60-0.90	0.04	0.05	1015
C 1015	Q, R	✓	✓	0.13-0.18	0.60-0.90	0.04	0.05	1015
C 1016	Q, R	✓	✓	0.10-0.23	0.30-0.50	0.04	0.05	1020
CB 1017	Q, R	✓	✓	0.15-0.20	0.30-0.50	0.04	0.05	1020
C 1018	Q, R	✓	✓	0.15-0.20	0.30-0.50	0.04	0.05	1020
C 1019	Q, R	✓	✓	0.15-0.20	0.30-0.50	0.04	0.05	1020
C 1020	Q, R	✓	✓	0.18-0.23	0.40-0.60	0.04	0.05	1022
C 1021	Q, R	✓	✓	0.18-0.23	0.40-0.60	0.04	0.05	1022
C 1022	Q, R	✓	✓	0.20-0.25	0.30-0.50	0.04	0.05	1024
C 1023	Q, R	✓	✓	0.20-0.25	0.30-0.50	0.04	0.05	1024
C 1024	Q, R	✓	✓	0.22-0.28	0.30-0.50	0.04	0.05	1025
C 1025	Q, R	✓	✓	0.22-0.28	0.30-0.50	0.04	0.05	1025
C 1026	Q, R	✓	✓	0.22-0.28	0.30-0.50	0.04	0.05	1025
C 1027	Q, R	✓	✓	0.25-0.31	0.60-0.90	0.04	0.05	1030
C 1028	Q, R	✓	✓	0.25-0.31	0.60-0.90	0.04	0.05	1030
C 1029	Q, R	✓	✓	0.25-0.31	0.60-0.90	0.04	0.05	1030
C 1030	Q, R	✓	✓	0.25-0.31	0.60-0.90	0.04	0.05	1030
C 1031	Q, R	✓	✓	0.25-0.31	0.60-0.90	0.04	0.05	1030
CB 1032	Q, R	✓	✓	0.30-0.36	0.60-0.90	0.04	0.05	1035
C 1033	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1034	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1035	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1036	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1037	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1038	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1039	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1040	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1041	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1042	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1043	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1044	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1045	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1046	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1047	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1048	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1049	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1050	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1051	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1052	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1053	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1054	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1055	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1056	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1057	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1058	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1059	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1060	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1061	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1062	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1063	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1064	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1065	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1066	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1067	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1068	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1069	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1070	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1071	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1072	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1073	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1074	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1075	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1076	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1077	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1078	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1079	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1080	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1081	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1082	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1083	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1084	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1085	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1086	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1087	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1088	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1089	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1090	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1091	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1092	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1093	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1094	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1095	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1096	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1097	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1098	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1099	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1100	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035
C 1101	Q, R	✓	✓	0.32-0.38	0.60-0.90	0.04	0.05	1035

Note 1: When silicon is specified in standard basic openhearth steels, silicon may be ordered only as 0.10 per cent maximum; 0.10 to 0.20 per cent; or 0.15 to 0.30 per cent. In the case of many grades of basic openhearth steel, special practice is necessary in order to comply with a specification including silicon content.

Note 2: Acid bessemer steel is not furnished with specified silicon content.

Sulphurized or Phosphorized Carbon Steels

ATIS Number	Semi-Finish	Bars	Wire Rods	C	Mn	P (b)	S (b)	'42 SAE Number
B 1106	Q, R	✓	✓	0.09 max.	0.50 max.	0.11 max.	0.04-0.09	1106
C 1106	Q, R	✓	✓	0.08-0.13	0.50-0.70	0.045 max.	0.07-0.12	1106
C 1107	Q, R	✓	✓	0.08-0.13	0.60-0.90	0.045 max.	0.08-0.13	1107
B 1108	Q, R	✓	✓	0.13 max.	0.80 max.	0.11 max.	0.045-0.075	1108
C 1109	Q, R	✓	✓	0.08-0.13	0.60-0.90	0.045 max.	0.10-0.15	1111
C 1110	Q, R	✓	✓	0.08-0.13	0.60-0.90	0.09-0.13	0.10-0.15	1111
B 1111	Q, R	✓	✓	0.08-0.13	0.60-0.90	0.045 max.	0.16-0.23	1112
C 1112	Q, R	✓	✓	0.08-0.13	0.60-0.90	0.09-0.13	0.16-0.23	1112
C 1113	Q, R	✓	✓	0.10-0.16	1.00-1.30	0.045 max.	0.08-0.13	1113
C 1114	Q, R	✓	✓	0.08-0.13	0.60-0.90	0.045 max.	0.24-0.33	1113
C 1115	Q, R	✓	✓	0.10-0.16	1.00-1.30	0.045 max.	0.24-0.33	1113
C 1116	Q, R	✓	✓	0.12-0.18	0.45-0.65	0.045 max.	0.075-0.15	1116
C 1117	Q, R	✓	✓	0.13-0.18	0.70-1.00	0.045 max.	0.10-0.15	1116
C 1118	Q, R	✓	✓	0.13-0.18	0.70-1.00	0.045 max.	0.10-0.15	1117
C 1119	Q, R	✓	✓	0.10-0.20	1.00-1.30	0.045 max.	0.08-0.13	1117
C 1120	Q, R	✓	✓	0.14-0.20	1.30-1.60	0.045 max.	0.08-0.13	1117
C 1121	Q, R	✓	✓	0.14-0.20	1.35-1.65	0.045 max.	0.08-0.13	1118
C 1122	Q, R	✓	✓	0.18-0.33	0.60-0.90	0.045 max.	0.08-0.13	1118
C 1123	Q, R	✓	✓	0.18-0.33	0.70-1.00	0.045 max.	0.08-0.13	1119
C 1124	Q, R	✓	✓	0.17-0.33	1.35-1.65	0.045 max.	0.08-0.13	1122
C 1125	Q, R	✓	✓	0.37-0.34	1.35-1.65	0.045 max.	0.08-0.13	1122
C 1126	Q, R	✓	✓	0.32-0.39	1.35-1.65	0.045 max.	0.08-0.13	1127
C 1127	Q, R	✓	✓	0.32-0.39	1.35-1.65	0.045 max.	0.04-0.07	1131
C 11401	Q, R	✓	✓	0.37-0.44	0.60-0.90	0.045 max.	0.04-0.07	1131
C 1141	Q, R	✓	✓	0.37-0.45	1.35-1.65	0.045 max.	0.08-0.13	1141
C 1144	Q, R	✓	✓	0.40-0.48	1.35-1.65	0.045 max.	0.24-0.33	1145
C 11451	Q, R	✓	✓	0.43-0.49	0.70-1.00	0.045 max.	0.04-0.07	1145
C 1205	Q, R	✓	✓	0.08 max.	0.25-0.40	0.04-0.07	0.05 max.	1205
C 1206	Q, R	✓	✓	0.08 max.	0.25-0.40	0.04-0.07	0.05 max.	1206
C 1209	Q, R	✓	✓	0.08-0.13	0.30-0.50	0.05-0.10	0.05 max.	1209
C 1310	Q, R	✓	✓	0.08-0.13	0.30-0.50	0.06-0.10	0.05 max.	1310
C 1211	Q, R	✓	✓	0.08-0.13	0.80-0.90	0.09-0.13	0.10-0.15	1211
C 1217	Q, R	✓	✓	0.14-0.19	0.70-1.00	0.09-0.13	0.20-0.29	1217



HERE'S WHY *Scrap* IS SO IMPORTANT!

SCRAP iron or steel turnings, clippings, short ends, worn out or broken tools, spoiled work, idle and obsolete machinery, etc., are valuable as raw materials for remelting in the production of new steel.

Through previous refining, ingredients undesirable in steel have been reduced—thus the use of properly prepared scrap speeds the refining process and enables new steels to be produced more rapidly. Recapture of scrap—from your plant—means opportunity to save time and labor—hence more steel.

Certain scrap contains valuable alloying elements such as nickel, molybdenum, tungsten, etc. which can and must be recovered to augment primary supply to meet tremendously increased demand for constructional and

high speed alloy steels for more planes, tanks, guns, ships, tools and machinery essential to the war effort.

To be of maximum immediate assistance, scrap should be segregated by composition wherever possible. Turnings, spoiled work etc. should be identified (SAE, AISI, NE etc. grade number) at the machine where they are generated and so handled as to avoid contamination by waste material or scrap of other types and grades.

The metallurgical experience of our staff is available to aid you in technical phases of metal salvage.

KEEP SCRAP MOVING INTO WAR PRODUCTION!

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET
NEW YORK, N. Y.

The importance of the 1942 National Metal Congress and Exposition warrants as full an account in Metal Progress as can be reported, for the benefit of ASMembers who could not attend—even though they were fewer in proportion than ever, as judged by the record breaking total of registration

Seven Aspects of the National Metal Congress

Steel Making and minor matters

By Frank G. Norris

IN CLEVELAND a few of the numbers that are particularly distinguished by having streets named after them are three, six, nine and twelve. Twelve is, of course, further honored by being permitted to have its street join with Euclid Avenue to form a corner for a popular hotel which, need I add, was at its popular ascendance during the Convention and Exposition. When I pulled into the unloading zone Monday morning the doorman asked if I had a reservation. I thought, "Well, this is fine—they must be expecting me." On entering the lobby I immediately saw about a half a dozen of my friends, which further contributed to the idea of cordiality. I excused myself from a group by asking my former boss if he would talk to Mrs. NORRIS while I arranged to get my room. He mentioned something about already having an engagement for the evening. Later on, standing in line for a room, the significance of this remark began to dawn on me!

A group of diligent air getters (you have probably heard the expression, "I think I'll go out to get a little air") finally located streets named after 4, 6, 7 and 8 but at this writing 5, 10 and 11 appear to have been distinctly unworthy in the early days of Cleveland. I think this conclusion is sufficiently tentative

that: 1. It will not be lonesome in the company of other conclusions. 2. It will not rise to haunt me after the report of some future research.

A source of satisfaction to most people is to make (or vicariously even to know of) a prediction that comes true, or to find agreement between theory and practice, or to arrive at an explanation for well founded but apparently contradictory facts. There were many instances of such satisfactions which, I believe, contribute to the feeling that this Convention was very much worth while. At least one theory was definitely disproved, viz., "There is not much use in going to conventions because the papers are printed in *Transactions*."

Realizing, however, that especially this year there are many who could not make the trip, this article (and its companions) is an attempt to bridge the gap between the strictly formal technical discussions that are available for reading in *Transactions* and the strictly informal discussions that will never appear in print.

British Production—The Cleveland Chapter of A.I.M.E. opened the fall season with an interesting and well attended meeting which was announced in some quarters as the Annual Fall Dinner of the Iron & Steel Division and the Institute of Metals Division. EARLE SMITH, Republic's chief metallurgist who had just returned from a mission to Great Britain, gave two examples of careful prediction or planning that none will forget. The navigator of a certain air transport had an error of three (or was

it four?) minutes in his estimated time of a trip that had a total length of some 11 hr. Again: During an air raid of a British blast furnace plant two bombs missed a particularly vital auxiliary by one landing 50 ft. on one side and the other landing 50 ft. on the other. The designer of this plant was in the room when EARLE gave this report and said, "I am glad to hear that I put that building in the correct spot!"

Here is a statistic that is worthy of more than passing attention: The number of blast furnaces in Great Britain is just a few less than the number in the United States; using almost the same number of furnaces and one-half the number of men, they make one-seventh the amount of pig iron we make.

Hydrogen — Several instances of agreement between theory and practice were brought out in the discussion of CARL ZAPPE's paper on Hydrogen. One point was the comparison of bleeding in 12% Cr and in the 17% or higher chromium-iron alloys. Another point was the effect of manganese on bleeding and on flaking. One is attributed to the hydrogen that is released from the liquid and the other (at least in part) to the hydrogen that is not released. Another part of the discussion that was distinctly dramatic was in regard to whether iron reduces water to release hydrogen, or whether hydrogen reduces scale. Several pertinent examples, including hydrogen embrittlement of boiler plate, were cited by various discussers and then ZAPPE of Battelle had the ball. A fumble now would be disastrous! This was no time to trust any of the boys; so he gave the ball to the old man and the law of mass action made a first down. You can read it all in the A.I.M.E. *Transactions*, and perhaps after several months it won't strike you this way, but it did me.

Luncheons — The requirements for attendance at an alumni luncheon have never been adequately defined. I have heard of a mining engineer from Colorado who gets an invitation annually from BOB MEHL to attend Carnegie Tech's meal. Personally, I attempted to participate in the one for which I had made reservation, but discovered that the larger rooms had more vacant seats. Of course there were also more filled seats, but it was a vacant seat that I was looking for. (I imagine that Dr. CHIPMAN could relate this situation to one of the three laws of thermodynamics.) I finally selected the larger group on the theory that I would be more acceptable here because my singing would be diluted by a greater number of voices.

Although holding no luncheon the Armco, Timken and Republic Alumni were represented by some distinguished members who took the occasion to renew old ties of friendship.

Tin Steel — A safe prediction is that we will be hearing some more about tin. In fact plans for future research were made right on the floor of the meeting. Prof. WALKER of the University of Illinois suggested that he would like to study steel of various tin contents with a micro-radiograph if he could secure the proper samples. J. W. HALLEY of Inland Steel Co. promptly said he would be glad to provide the material. There is a small obstacle in the matter of magnification, since the micro-radiograph is effective at not much over 200 diameters, whereas the grain boundary precipitate found with high tin is disclosed at 2500 diameters. In any event HALLEY's paper has stimulated future work, which is one of the purposes of publication.

GERHARD DERGE of Carnegie Tech, by the way, is willing to test the hardenability of tin steels and collect data whereby ideal hardenability can be computed by Grossmann's methods — if the work is not already under way. Is anybody else working along these lines?

Help, Help! — Another purpose of technical meetings in general and the 1942 Metal Congress in particular is to provide information and help to those with a definite problem to solve. A list of all such instances would be impossible to compile. Two are selected as typical:

One man asked for some definite information on the duplex process, and it was promptly provided. The benefit of this one discussion attests the wisdom of repeating the McKune Prize Paper at the next meeting, although the authors were modestly reluctant to do so.

A metallurgist with an aircraft manufacturer was seeking advice on meeting the requirements of a particular part. He secured several suggestions.

Not to be neglected in a report of papers of importance to steelmaking is "Equilibria of Liquid Iron and Simple Basic and Acid Slags in a Rotary Induction Furnace", by CHARLES R. TAYLOR of the Armco staff and JOHN CHIPMAN of Massachusetts Tech. I will have to read the discussion of this paper in A.I.M.E. *Transactions* because it is simply impossible to attend two sessions, each scheduled for 2:00 o'clock, especially when one is in the Statler Hotel and the other is in the Cleveland Auditorium. I elected to attend the latter session, for it would not be recorded. This TAYLOR-CHIPMAN paper was

re-scheduled from the last February meeting, and it deserved a better place on the program.

Silicon received its proper share of attention. The question frequently rises as to whether silicon in the openhearth charge is a necessary evil or an unmitigated evil. This question in a slightly altered form was asked by JOHN MARSH. The answer was that the lower the silicon the better, and JOHN said this answer agreed with his opinion. It was not entirely clear whether "the better" meant better for tons per hour, or better for the chemical analysis. (I almost wrote "better for quality", but refrained because I remembered that quality can be discussed only in relation to ultimate use.)

BILL REAGAN (now of Copperweld Steel) likes to ask a closely related question, "How far can the limestone be cut on low silicon charges?" With the charges and applications that I know of, it seems to me that high sulphur will be the first indication of too low lime, and sulphur will show up to serve as a warning before any more subtle detriment creeps in. BILL remembered this answer, and used it as a prod some two or three years later. Now comes VERNON JONES, assistant superintendent of openhearth for American Rolling Mill Co., with some evidence on the matter. In describing the process which his associate CHARLIE FONDERSMITH playfully refers to as the bessemer he was never permitted to buy, VERNON reports very uniformly controlled silicon at a low level. Here is an ideal chance to cut the lime charge to the bone. The amount used could be only that which is absolutely necessary, because no margin of safety would be required to provide for unexpectedly high silicon in the charge. Here is his answer as I remember it (and you can't go to *Transactions* on this one): With the lower silicon iron (0.40%) they expected to be able to go to a 3% lime charge, but found that phosphorus removal was unsatisfactory, and therefore could not get down this low.

One interesting section of the Campbell Memorial Lecture, all of which incidentally will reward careful study, dealt with silicate structures in slags. I wouldn't doubt but what this may have something to do with BILL REAGAN's question and maybe with JOHN MARSH's. Dr. CHIPMAN surpassed himself in this lecture. It must be passed by here for lack of space. The Editor also says *Metal Progress* will avoid abstracting it in this issue for it

will be published in full in *Transactions* for December.

Refining Reactions — ZAPPE and SIMS of Battelle Memorial Institute have given us something else to think about in connection with silicon and oxygen in liquid iron. Starting from the data which they have, their conclusions follow inexorably from sound thermodynamic considerations. This is not merely my opinion, but the considered judgment of one who is as straight in his thinking as he is in his chalk tossing. With this assurance I am willing to talk about the existence of silicon monoxide (!) in liquid iron and to consider the solution of SiO_2 as a stepwise process. (As Dr. CHIPMAN mentions, it is possible to make use of a concept without believing in it.) The authors are to be thanked for expressing their results in understandable terms and especially for including some sample calculations at selected representative temperatures. Sometimes in a paper of this sort — because of the whim of either the author or the editor — the results are expressed in the form of an equation and the reader is gleefully left stranded to muddle back to familiar territory as best he can under his own power.

The last of the references to silicon that I am going to mention is the paper by JOHN CHIPMAN and his associate N. J. GRANT on the heat of solution of silicon in liquid iron. As nearly as I can tell from a casual reading, ZAPPE and SIMS use 115,500 cal. for the oxidation of silicon to SiO_2 by FeO at 1600°C . CHIPMAN and GRANT give 180,000 cal. for the deoxidation of iron by liquid silicon at 1600°C . One is apparently the same as the other, in reverse, and there isn't any way I know of to make 115 look like 180. Maybe there is some little trick that I have overlooked. (Hitler and Goebbels probably could do it.)

It would have been interesting if CHIPMAN, GRANT, ZAPPE or SIMS had given some values for the amount of heat absorbed by the ladle



as related to the amount of preheat and the number of heats poured, but perhaps this is expecting a little too much. The calculated heat effect of 75% Si and 50% Si confirms the practical observation that 50% ferrosilicon is not a source of heat with a large ladle addition. The borderline composition where the heat required by the cold addition is equal to the heat of solution, in which case the over-all effect is neither heating nor chilling, is about 62% silicon. It doesn't matter much whether the addition is all 62% ferro or whether it is a mixture of 50% with some higher alloy to give an average of 62%. The necessary data are all in CHIPMAN's paper and you can figure it out some day when you are waiting for the heat to cool off enough to pour. With a large enough addition this is a good little while.

Scrap — A scrap drive is a one-time source of raw material. The only permanent way to increase steel production is to reduce more ore which with a few notable exceptions means to shove more ore through the blast furnace. An increase of pig iron production from 71 to 85 or more million tons is anticipated. For most shops this will mean that the openhearth must learn to use high iron charges. A big part of this problem is not metallurgical but is a matter of transportation, or railroading — however you want to think of it. ("Expediting" is the popular cliché.) Broken down in this way the logic of establishing a new job is understood. This man might be called the "charger" because his duties are of an importance probably equal to those of the melter. He should be responsible for getting all materials (both scrap and hot metal) to all of the furnaces at the proper time. In other words, he coordinates the stock house, the mixer, the switch engine, the transfer car and hot metal crane to the furnace's needs.

Electric furnace shops and makers of alloy steel will feel the scrap shortage the worst. Some grades now being made in the openhearth may be made in the electric to save chromium and manganese or for quality. A need is felt for an over-all general authority for scheduling the production of each company, rather than depending on plant location, customer relations, ability of the sales force and similar considerations to influence the type of orders turned out by various mills.

Women's Work — In England 13½% of the employees in the mill are women. In some mills women are holding such jobs as chippers and blooming mill rollers. English experience in

machine manufacturing is that when 60% of the jobs that women can do are filled with women, production is increased by 50%. When 70% of women's jobs are filled with women the officials are disappointed if production is not doubled. In other words there have been too many men doing women's work. It is of equal importance to keep in mind that certain jobs are men's jobs, and if women are put on them they break down after a few months.

Show — Now the technical report is over and we can wander for an hour or so through the exhibits. I suppose you could browse down the aisles 50 times and see new things and get new ideas each time. It seemed to me this year that the attendants had a story that they were anxious to tell — once. If you were not interested after having been informed, you were expected to pass along; no high pressure methods were in evidence. If you were interested an abundance of useful suggestions was available. The various applications of a particular product or process are not always immediately apparent to the casual observer, so it is well to pause a little even though you may think you have no use for the product.

One example is probably representative of many such cases: I had thought that a sheet manufacturer's chief interest in degreasing was to use an oil that the customer can remove satisfactorily from the sheet. I found, however, that there is an application of a degreasing idea right in our own plant which saves considerable time in removing heavy grease from strip mill bearings during repairs.

Trivia — A sight of considerable interest to strangers which veteran Clevelanders allow to go by with complete indifference is a string of "half-tracs" out on a test run. If I were a school boy looking for a prolific source of scrap metal I would find where these babies sleep, and try to get the neat little package of ballast that each carries!

If you know who made these remarks when, you were either at the convention or have a pretty good idea of what it was like:

"I have your name right here and you will have a room as soon as anyone checks out."

"What goes into the furnace must come out — unless it stays in."

"Sorry to have to rush off but I have to catch the six o'clock train." (What a train that must have been if everybody caught it!)

"I couldn't get a reservation until Monday so I'm going to fly back."

Heat Treatment

AS EARLY AS 9:30 A.M. Monday morning, October 12th, a sufficient number of A.S.M. members had appeared at the Hotel Statler to fill to capacity the parlors provided to discuss papers on steel properties.

O. W. BOSTON and L. V. COLWELL's paper on "The Effect of Hardness on the Machinability of Six Alloy Steels" should be of considerable interest to production-minded machine shop superintendents trying to obtain maximum results from over-burdened armament plants. The authors, by careful standardization of testing procedure, determined the relative machinability of six nickel-chromium and nickel-molybdenum steels at various hardnesses. The authors noted, among other things, that the steels with highest hardenability machined more readily at high hardness than did the steels with lower hardenability. More than one of the discussers suggested that this effect could probably be explained on the basis of microstructure; those steels with high hardenability probably resulted in a very uniform structure after quenching and tempering. Steels with lower hardenability, though having the same nominal final hardness, were probably of non-uniform microstructure.

D. H. ROWLAND and O. E. ROMIG also presented an interesting method for obtaining superior results in the metallographic polishing of galvanized sheet. The word "galvanized" in the title should not deter any ferrous metallographer from reading the paper. A new method of obtaining metallographic alumina (without levigation) by calcining aluminum sulphate is explained.

Hardenability Session — "Standing room only", and very little of that, was available when MORSE HILL, G. R. BARROW and GILBERT SOLER presented papers on hardenability.

Mr. HILL's paper on the end-quench hardenability test was followed by lively discussion indicating the general interest in the subject and its timeliness. One point made evident was that the reproducibility of the test, if a few precautions are taken, is considerably better than required from a practical standpoint. Variations in the steel caused by segregation, forging and the effect of prior structure are much greater than the variations normally encoun-

tered because of changes in water temperature and head, and other experimental errors.

Messrs. BARROW and SOLER, in their paper entitled "Hardenability Control of a 1% Carbon Steel" found that the end-quench method was not sufficiently sensitive to give satisfactory discrimination for steels of low hardenability. Complete quenching of standard rounds is better for shallow hardening, high carbon steels. By taking account not only of carbon, manganese and silicon, but also of the incidental elements, phosphorus, chromium and nickel in such a steel, the authors found they could successfully predict its hardenability.

Tool Hardening — In a session late in the week somewhat diverse opinions concerning the austenite → martensite (or bainite) transformation during the quenching and tempering of high alloy toolsteel were expressed, and vigorously argued, by PETER PAYSON and J. L. KLEIN of Crucible Steel Co. of America, on the one hand, and MORRIS COHEN and associates at Massachusetts Institute of Technology, on the other. These are described in more detail in the report on Fundamental Metallurgy, page 895.

Possibly the different conclusions are due to different experimental techniques — PAYSON judged conditions principally by microstructure, and COHEN by time-dilation curves. At any rate, PAYSON insists that interrupted quenching for isothermal transformation is not good tool-hardening practice. Commercially only 10 to 15 min. is allowable at intermediate temperatures to reduce the surface-to-center gradient of the heavier tools (and so decrease the internal strains) or for straightening operations. Transformation to hard martensite is not an isothermal transformation, but will occur as the temperature decreases, in the range from about 400 to 80° F., independently of the cooling rate in that interval. Substantially complete transformation should take place before tempering starts, so "it is faulty practice to temper tools before they have been cooled throughout in the quench to about 100 to 150° F."

Production Hardening — In the round-table discussions one of the talented arrays, chairmanned by ROBERT B. SCHENCK of Buick Motors, considered problems of production hardening. A recent study was made by one of the experts on the "sluggish steels" S.A.E. 4140, 4240 and 4340. End-quenched tests were made on these

steels in four microstructural conditions, namely, spheroidized annealed, as hot-rolled (somewhat banded), normalized, and pre-quenched. It was discovered that the end-quench test curves were unchanged by any reasonable quenching temperature (40 min. hold), if the temperature rises above the point where solution is attained. Time at quenching heat up to 4 hr. very slightly decreases the hardenability of all the structures except the spheroidized, where there is a marked increase in hardenability with time at 1525° F., the quenching temperature used. The conclusion is, of course, that time at quenching heat can frequently be reduced in commercial work — if the piece really is at quenching heat.

NE Steels — Producers and consumers freely exchanged all available data on the national emergency steels at two notable round-table discussions — the new type of technical meeting that is bringing back a freer flow of information between speaker and audience. About 15 experts gave brief statements concerning this or that aspect of the general subject, and were then open to comment, question or rebuttal from the floor. Both meetings stressed the fact that American metallurgists must complete a conversion task in a few months which normally would require ten years.

It is expected that most of the material so presented will be printed, in some form or another, but meanwhile a few comparisons may be stated, all based on plant experience with numerous full-sized heats.

1. NE8630 has been found by one large consumer to have slightly *better* impact strength than S.A.E. 4130 or 3130, both at room temperature and sub-zero temperature.

2. In shifting from S.A.E. 4620 to NE8620 and NE8720 another consumer found somewhat increased tool life, and no increase in trouble from either banding or distortion.

3. In many instances a considerable reduction in annealing time can be achieved by shifting from S.A.E. steels to NE steels of equivalent hardenability. The time saving is easiest when furnaces are such that constant temperature transformation is possible (see Mr. HAFSTEN's article on page 869).

4. NE steels are capable of doing as good a job as S.A.E. steels in 98% of the cases.

In changing from an S.A.E. steel to a national emergency steel, select a grade of comparable hardenability with approximately the same carbon content. Avoid increasing the car-

bon content to get added hardenability, unless advised to do so by the steel producer, for it will probably bring on greater distortion and quenching troubles. Avoid decided increases in hardenability just to obtain an additional "safety factor", for increased hardenability means increased use of valuable alloy.

Both producers and consumers agreed that a savings of 50% in critical alloys could be accomplished by shifting to NE steels. Chairman CHARLES M. PARKER sounded the keynote with the statement that "The success of the NE steels is just as vital to this country as are Navy and Army victories".

Metal Show — From numerous notes taken at the Exposition, one remembers that Lindberg Engineering Co.'s film, "Heat Treating Hints", was shown hourly to crowds frequently too large to be seated. This color talkie presented several interesting ideas and methods for obtaining better service and life from hardened tools and gears. (This film is available for showing at plants and group meetings.)

The present trend toward induction hardening, brazing, annealing and heating was emphasized by conspicuous displays of three different companies building induction heating equipment. The various methods of surface hardening by differential heating — electric induction, oxy-acetylene flame, gas-air burners — were presented at one of the round-table discussions. Proponents of each method claimed far superior transition structures between hardened surface and unaffected base, as measured by a gentler hardness gradient or more gradual microstructural change. It might appear that sharpness of gradient is associated with speed of the operation — superficial hardening in less than a second by high frequency electrical currents is a modern miracle in mass production, but the very time element prevents the transfer of much heat into the body of the piece, and thus makes for a sharp demarcation. In flame heating, the mass of the piece — far from being a hindrance to surface hardening — is an advantage since the cold center effectually quenches the piece; the hot surface layers, sprayed outside, are in fact quenched from both directions. While there are many overlaps, induction hardening seems to be favored for relatively simple shapes like cylindrical surfaces, whereas flame hardening is chosen for large, irregular surfaces, or for spot hardening, or in places where hardening equipment is needed in a great hurry.

Welding Highlights

By Joseph V. Kielb

AT THIS CRITICAL PERIOD of the war program, the American Society for Metals and the American Welding Society gathered to discuss vital points that have developed in the past year. At all the sessions, new findings in all phases of welding were revealed by the welding men and each individual profited by the experiences of others. A certain amount of tension created through the effort to fill war orders was visible.

From the opening session on Monday until the last session on Friday, each conference was fully attended. All papers were presented in an excellent manner and the audience carried on much general discussion. Each individual seemed to be there with the definite purpose of collecting some new information pertaining to his particular job. Welding sessions contained lectures on all types of welding and cutting which exist in shipbuilding, aircraft and industrial plants, and included much matter on the recruiting of women and training of personnel.

Several of the papers included the combined work of welding engineers and metallurgists. Many new developments required the cooperation of both departments in order to tackle the problems encountered in production.

Substitute or Modified Steels — Weldability of steels is such a topic, requiring the knowledge of both metallurgist and welding engineer. Another is the handling of new and modified substitute steels recently developed. New procedures and techniques are being used for welding these steels, but final appraisal of weld metal structure depends on the decision of the metallurgist; an example in aircraft is the replacement of X4130 by NE8630. Another meeting discussed carbon-manganese steels, their hardness, effect of plate thickness, single or multiple pass welding, and like matters.

NE8630 steel is higher in manganese, silicon and nickel content than X4130, while chromium and molybdenum are slightly lower. It was noticed that the welding qualities were closely related to X4130, but welding techniques varied slightly. It was said that welding wire with a lower carbon, ranging from 0.05 to 0.12%, silicon of 0.05% max. with no molybdenum and little or no chromium gives better results in the welded area than welding wire with higher

carbon, manganese, silicon, chromium and molybdenum. Test specimens showed that the higher alloyed welds cracked in the welded area or in the fusion zone, before complete bending of the longitudinal bend specimens. The microstructure revealed martensite in the fusion zone.

This condition was improved by oil quenching from 1550° F., followed by 1 hr. at 900° (which A. P. LITTLE recommended). This heat treatment improved the tensile qualities of all the weld metal areas; however, high qualities often prevailed in welds made with the high carbon and alloy wires. It was also mentioned that in many aircraft plants, different rods are being used without a control specification of chemical analysis, varied as necessary in respect to the types of metal being joined, and the speaker presented a suggested specification. While this particular paper pertained to oxy-acetylene welding in aircraft, it is recognized that arc welding is being highly developed and proving satisfactory in this industry. Welding wire is controlled under specifications set up by the A.W.S. codes on electrodes. Effects on structure within the arc welded area, re-design to aid the welder, the effects of hard areas, locked-up stress and internal strains created by arc welding — all are under investigation.

At a later session it was revealed that a general survey had been made of all aircraft plants on both East and West coasts, and it was a pleasant surprise to find that a greater degree of standardization is being developed than would have been surmised from earlier discussion. Cooperation was observed in industry both here and abroad, as markedly shown by men from all parts of the United States and Canada attending these sessions. England had two representatives at the sessions to give some of their experiences, and in return to receive new ideas to take back with them.

Hardness of the Joint — The session on weldability of steels brought forth much talk about the hardness developed at the welds in carbon-manganese steels. Most of the research along this line has been carried out by universities interested in welding problems, and has been sponsored by the Welding Research Committee of the Engineering Foundation. An important part of the study related to technique of plate welding in relationship to the hard area created. Next was the question relating to the



Massive Spot Welder For Thick Plate Wherein the Welding Current as Well as a Second Cycle for Heat Treatment Is Automatically Controlled by a Thermocouple Built Into the Refrigerated Electrodes (Progressive Welder Co.)

diameter of the electrode as it affects the depth of hardness in the base plate. Numerous hardness readings around the fusion zone were higher than the weld metal and the base plate, and cracks developed in welded zones of 460 to 485 Brinell.

A test for carbon-manganese steels (a Tee-joint with top plate bent on 12-thickness span so that the fillet welds are on the tension side) has been developed by the Navy Department and is used by many research laboratories. In such a bend test cracks are developed in all sections of the welded area — the throat section, and the horizontal or vertical leg of the weld metal of the fillet. Tests have been carried out on material preheated to 300, 600, and 900° F. before welding; generally single pass fillets were employed.

In a careful study along these lines by LEON C. BIBBER and JULIUS HUESCHKE of Carnegie-Illinois Steel Corp., it is concluded that the total angle of bend at the *start* of failure is the best criterion of weldability or usability of the material. Incidental and unknown variables in the welding or testing appear to have more influence than minor variations in the chemical analysis of the steel. The same is true of the grain size and method of manufacture. It was concluded therefore that while the low carbon, low manganese steels are most weldable, and the high carbon, high manganese steels least

weldable, the Tee-bend test cannot clearly differentiate usability of intermediate grades.

What would be the effect of the hard regions if vibration tests were given to such Tee-bend specimens? Although alternate stress tests on welded areas with different types of welded joints made with different electrodes are not often discussed, it has been known that welds having hard spots in the fusion zone have cracked in the throat and the legs of the weld metal under fatigue, even when the joints have been made after optimum preheating.

Additional thought might be given to the hardness relations when joining various types of steel — such as high tensile steel to mild steel, high tensile steel to special treated steel, or mild steel to special treated steel, as affected by the various types of electrodes, and the method of welding, whether single pass or multiple pass. Some rather unexpected results of hardness surveys were reported, but the depth of hardness in all cases depended on the diameter of the electrodes, thickness of plate and preheat temperature. If a series of tests with single pass welds gives questionable results, then the multiple pass should be tried, since this method changes the hardness of the previous layers in all zones. The amount of change depends on the technique — that is, the beading, intermittent, or weaving techniques. The weaving method anneals the previous layer and changes its hardness in approximately two-thirds of its depth. This results in a more uniform structure. The other two methods increase the hardness due to the limited but localized heat within the welded area and occasionally hardening cracks develop in the fusion zone due to its rapid cooling by the base metal.

It would be a difficult assignment to combine all the hardness data on different steels with relation to the thickness of plate, size of electrode, single or multiple pass welding, heat treatment before and after welding — to mention but five variables — but such a text would be an invaluable aid to the industry and further its understanding of present day conditions, where much steel other than mild carbon steel must be safely welded. W. F. HESS, who is in charge of the welding laboratory at Rensselaer Polytechnic Institute, is planning to do just that in his study of cooling rates on the properties of arc welded joints. This work will aid many welding engineers who are having trouble with cracked welds from locked up stresses and internal strain developed during welding.

Cutting of Steel, and Tools Therefor

By O. W. Boston

SINCE SO MUCH of the information on toolsteels, tool materials, tool design and machinability was given in round-table discussions, where individuals should not be quoted by name, this report will be of a somewhat general nature, with no attempt made to be consecutive or chronological.

Toolsteels — One difficulty the production man must meet is the changeability of his tool materials, a matter which is apparently much more prominent in high speed steel than in the cast non-ferrous tool alloys and the cemented carbides. Official opinion seems to be that the alloys used in making cutting tools should be saved for the production of more alloy steel. Constant consideration must be given to the supply of such elements as tungsten, molybdenum, cobalt, vanadium, chromium, titanium and tantalum. Current consumption of some of these is greater than the production, although this condition varies, and the types of tools most appropriate to use will also vary. At the present time, much 18-4-1 high speed toolsteel is available but the molybdenum types constitute the greater tonnage in use.

At present, about 65% of the molybdenum high speed steel tools are of the 5.25% W, 4.5 Mo type; 20% of the tonnage is of the 8.5% Mo, 1.5% W type; and 15% is of the 8.5% Mo, 2% V type. It is expected that, by the end of the year, the first mentioned type — which is suitable for general purpose tools — will be increased to 70%. From one-quarter to one-third more tools will probably be needed in 1943 than will have been used in 1942.

An interesting point picked up in the discussion concerned chromium plating of high speed tools. After a thin electroplate the tool is tempered for one hour at 350° F. for a more gradual transition from plate to steel. Some such tools are reported to have given greatly increased tool life, particularly on light cuts.

Standardization of toolsteels and tools will result in as many economies as standardization of other mass-production lines has effected. A reduction in the number of grades of toolsteels will lead to greater mill output and less confusion in storage. (However, seemingly small chemistry alterations may change performance

greatly, and probably necessitate changes in heat treating practice — as was pointed out in a discussion of toolsteels without vanadium —) but standardization of analyses would be very difficult at this time, because of the changing availability of strategic elements.

Another approach to the problem will bear fruit: A more general use of common standards of size and tolerances would avoid frequent roll mill changes and result in increased mill production. Several customers may require steel a given size but one wants a plus tolerance, the second a negative tolerance, and the third a bilateral tolerance, making it difficult or impossible to run all at one setting of the mill. Yet it occurs frequently that these bars are finally ground to the same final size of tool!

Carbides — Considerable information was presented about carbide tools, not only their composition but also their design. The plain sintered tungsten-carbide tools with cobalt binder are used most generally in machining those metals producing broken-up chips, such as cast iron, together with some copper alloys. For machining ferrous metals which produce curly chips, sintered combined carbides are preferred; these often consist of tungsten, titanium and tantalum carbides mixed with a suitable binder, chiefly cobalt, compressed to a convenient form and heated until fusion of the binder has effected complete coalescence and union of the carbide particles and developed maximum resistance to deformation.

The amount of binder alters the hardness, strength, resistance to mechanical and thermal shock, and to abrasion. With the low quantity of binder, from 3 to 5%, maximum hardness is obtained with lowered shock resistance. With the highest binder, say 15% or more, strength and resistance to impact are greatly increased, but at the expense of hardness and resistance to wear. It is not now possible to have both maximum strength and maximum hardness in the same carbide tool. The most widely used tool grades are those with intermediate cobalt content to give a good combination of general properties. Present practice is to adapt sintered carbides to a very wide use, from swaging and cold heading dies, tools for planers and shapers and those for heavy intermittent roughing cuts, to the hardest grades used for fast finishing cuts on hardened materials.

Tool Design is a point equally important to future development. Current practice is to use less back and side rakes on carbide tipped tools, frequently both rakes are negative. For heavy interrupted cuts, as on shapers, the back rake may be as high as 45° negative. These negative rake angles increase the lip angle, strengthen it and make it better able to withstand shock, as well as bring the point of application of each new cut back some distance, from the point of the tool, where the carbide tip is stronger. Negative top rake frequently enables the tool to be used without a chip breaker. This saves trouble and time in grinding.


Small nose radii have been found to work better on these tools. A $\frac{1}{32}$ -in. radius is large enough for ordinary feeds, while $\frac{1}{64}$ in. is sufficient for the heaviest cuts. In grinding the tools, extreme care must be used in preventing grinding cracks. Avoid loading the abrasive wheel by grinding both steel from the shank and carbide from the tip.

A little extra care in the tool room will do wonders in increasing tool life. For cemented carbides, fine tool finishing may be done with 120 and 220-grit silicon carbide wheels, or with a 220 to 400-grit diamond wheel, to produce a surface quality of 2 to 5 micro-inches. For the same tool finish, the diamond grit should be finer than the silicon carbide grit, inasmuch as the diamond points become dulled less rapidly. Grinding marks should be parallel to the motion of the chips.

Inserts and Composite Tools — Whereas little can be gained in reducing further the alloys in high speed steel, many tons of the steel can be saved by tipping, or using bits of toolsteel and shanks of ordinary steel. Small pre-formed pieces of the high alloyed metals may be attached to a shank of medium carbon steel by clamps or by a cement which melts at the hardening temperature, or by brazing solders that melt at about 1000° F. (which is lower than the tempering temperature of the tips). Tips of cast chromium-tungsten-cobalt alloys may also be welded to steel shanks. Cemented carbide tips are brazed to ordinary steel shanks. Tools tipped with cemented carbide now contain much less critical alloy by weight than solid high speed steel tools, so that of two tools of comparable size, the former type would be the cheaper. Useful standard sizes of bits and tipped-tool shanks are now available; in many present-day applications excessive amounts of strategic alloys are being employed.

Machinability

Much curiosity about the machinability of NE steels was unsatisfied because shop experience with them has not yet been sufficient to draw many conclusions, other than the obvious ones that no great difficulty is being experienced, but that considerable work will be necessary before optimum conditions are established for important jobs. This is especially true of the NE9000 series, recently formulated but which will be pressed into service as fast as possible on account of the fact that they require little more alloy than can be saved from the well segregated scrap being remelted.

A procedure for setting up satisfactory cutting practice for the NE steels suggests itself in a technical paper on the machinability of six alloy steels at high hardness, which was presented before the  by O. W. BOSTON and L. V. COLWELL of the University of Michigan. This paper emphasizes the very great sensitivity of cutting speeds and tool life to small variations in the hardness of the steel being machined. This fact indicates that considerable care should be taken in the heat treating operations to produce consistently uniform hardness of the part in the region that is to be machined. It may be difficult to do this with those NE steels which have poor Jominy hardenability, but once uniform hardness has been given the parts it will not be difficult to machine them.

Many comments were heard on the constant trend toward the machining of steels at higher and higher hardness levels. For example, steels of 400 Brinell are now being machined commercially whereas those of 250 to 300 Brinell were thought to be the upper limit only a few years ago.

For mass production the material should be of the proper analysis, structure and ductility, the tool should be of an appropriate material, design, shape and finish, the cut properly proportioned between depth of cut and feed, the cutting fluid of correct type, applied in large quantities at low temperature, and the cutting speed adjusted to get the greatest amount of chip removal per tool grind for the desired rate of production. It is possible to vary the rate of production by more than 100% by fairly small changes in these various factors.

Structure Vs. Machinability — NORMAN E. WOLDMAN's work was cited as one of the few attempts to correlate the structure with a specific type of machining operation. One struc-

ture was found best for turning small gear blanks, another for hobbing, a third for planing the gear teeth. In general, however, the automotive and machinery industries have found that low carbon steels should be fully annealed to present a lamellar pearlitic structure. For the steels of higher carbon, a spheroidized structure is more desirable, although if a good finish is desired, a sorbitic structure seems to give the best finish but a poor tool life.

With low carbon steels, it is desirable to break up the continuity of the soft and ductile ferrite. This is done by the addition of small amounts of sulphur, lead or selenium. The sulphur, commonly used to produce screw stock, forms sulphides which greatly improve the machinability. X-1335 steel is a good illustration of a steel containing manganese sulphide which can be machined at a high hardness desirable to resist wear. Silicate inclusions may also break up the continuity of the ferrite, but they are abrasive and reduce the tool life.

Low carbon steels, especially where no alloy is present and where manganese is low, if machined in a hot rolled condition will produce a long and continuous chip which is a definite nuisance. Large unbroken areas of free ferrite are the principal offenders in this case. As the cutting edge of the tool passes through pearlitic areas where the hardness is comparatively high, the material fractures easily. Then, when the cutting edge progresses to a particle of ferrite, the tool point is resisted by the soft, rubbery tenacity of this constituent and, instead of fracturing, the material tears and pulls, producing a rough, ragged finish and long, continuous

chips. Analyses which are high enough in carbon so that less free ferrite is present and more pearlite are less and less subject to the trouble outlined above until a point is reached where the reverse becomes true.

Among the straight carbon steels, those containing less than about 0.30% carbon are especially subject to poor machining because of softness. Those steels having from 0.30 to 0.45% carbon may give somewhat better results, and those containing above 0.50% carbon should be annealed for machining to produce a suitable microstructure.

For those steels below 0.30% carbon, a suitable normalizing heat treatment or even quenching may stiffen the structure sufficiently to aid machinability and tool life. Cold working, however, has many advantages over any other means of improvement, even though the steels may be resulfurized to improve machinability. A moderate amount of cold drawing is sufficient. If the steel is cold drawn to too great a percentage, it becomes too hard for favorable tool life. In addition to improving the machinability the cold finishing produces close dimensional accuracy which frequently avoids much work.

Structure has a pronounced effect on the nature of the chip and on the surface finish. Fine grained steels have better hardenability and produce a better machined surface but with correspondingly lower tool life than the coarse grained steels which have poor hardenability, produce a poor surface quality but give a long tool life.

The new W.D. 1050 steel with increased manganese, used for (Continued on page 922)



Convention Report

Non-Ferrous Section

By F. N. Rhines

THE MODESTY OF THE EXHIBITS of the non-ferrous industries at the National Metal Exposition was true evidence of sincerity in diverting nothing from the war effort. Most of the familiar exhibitors of happier years were represented, but few showed metals—some showed items of military materiel, to be sure, little else.

With the equally commendable purpose of acquainting the war industries with their latest advances, the manufacturers of fabricating, testing, and inspection equipment outbid themselves in the number and diversity of devices exhibited. X-rays almost stole the show! There was everything from near-miniature radiographic and X-ray diffraction machines to a giant million volt radiographic tube that looks like something from Mars. The emphasis was on portable equipment of all sizes. An extremely interesting exhibit of micro-radiographs and micro-radiographic equipment was displayed by General Electric Co. Incidentally, pure beryllium metal made its initial bow; it is being used for X-ray tube windows.

One of the pleasantest features of the Exposition lay in the evidence that it gave of the rapidity with which machinery and devices, formerly imported, have been produced in this country. For example: Swiss type automatic screw machines, optical devices, and special kinds of X-ray tubes.

New Alloying Method—In the course of a research that began as a study of the nature of inverse segregation, M. L. SAMUELS, A. R. ELSEA and K. GRUBE developed a new and ingenious method for making certain alloys that have been otherwise difficult to produce. Thus: A cast alloy having a very long freezing range, copper-bismuth or aluminum-tin for example, is heated into the temperature range of liquation in a vessel provided with an opening at the bottom. If a low melting metal, such as lead, is then poured on top of the partly melted casting the liquated phase (bismuth or tin) is forced out at the bottom and is replaced by the metal (lead) that was poured on top. In this manner a cast copper-lead alloy containing anywhere from 20 to 80% of lead can be made. Formerly, as in the manufacture of bearings, this could be done only at the risk of extreme gravity segre-

gation or by the powder technique. Similarly a broad range of aluminum-lead alloys can be made when no method has heretofore been wholly successful. In fact, the procedure is adaptable to a wide range of alloys. It was pointed out, however, that it inevitably produces a considerable quantity of contaminated low melting alloy that may be difficult to dispose of and expensive to refine.

Copper Alloys—A comprehensive study of the influence of ten alloying elements, in binary alloys of copper, upon hardness, rate of work hardening and recrystallization was presented by R. M. BRICK, D. L. MARTIN and R. P. ANGIER. Where the grain size is held constant it was found that solution hardening is linear with atomic percentage over a broad range for most elements and is related in a non-linear way to the change in lattice parameter. Rate of strain hardening also increases linearly with atomic percentage of the alloy. Annealed structures of those exhibiting the greatest hardening showed the least effective preference in orientation.

Another study of the mechanical properties of copper alloys dealt with the effect of several additions upon tensile strength at slightly elevated temperatures. The progress of a test specimen, through the sequence of yield stress, maximum stress and ultimate stress, was graphically and humorously likened to the progress of a drunk as he first yields, gets high and goes out (all load on the way home) by E. R. PARKER and C. FERGUSON, who found that at 200 and 300° C. (390 and 570° F.) the load required to rupture copper in 1000 hr. is scarcely half that required in a normal rapid test. Several of the alloying agents added to copper in small percentages greatly improve the ratio of short-time to long-time rupture strength, perhaps because they prevent annealing at these temperatures. In this connection it was shown that in the long-time test the rupture in copper is intercrystalline, while it is trans-crystalline in those alloys that retain their short-time strengths in the long-time tests. Thus the established concept of the "equi-cohesive temperature" reappears with alterations and improvements.

Miscellany—HOWARD S. COLEMAN and HENRY L. YEAGLEY have devised a rapid optical method for measuring the activation heat of intermetallic diffusion; the method was applied to the gold-lead and copper-zinc systems with



In the Show, Extensive Use Was Made of Murals

gratifying success... For considerably more than a half century the metallographers and their allies have been engaged in building up a library of phase diagrams of the alloy systems, yet but few diagrams of the high melting alloys are on record. There is great satisfaction, therefore, in being able to add another hard-won diagram to fill a vacancy in this group. FINLEY H. ELLINGER, in the face of tremendous difficulties, has outlined the chief features of the tantalum-carbon system and presented a diagram. ... In a timely paper on the metallography of commercial magnesium alloys J. B. HESS and P. F. GEORGE described the best methods for preparing specimens for examination and gave a series of photomicrographs of the typical structures.... TABER DEFOREST has added another interesting trick to the methods available for detecting surface cracks in non-ferrous castings. By the use of a penetrating fluorescent substance the cracks are visible under ultraviolet light.

Rare and Precious Metals

Wartime curtailment of publishable research was felt in the small number of papers presented before the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, but the brevity of the program was more than offset by an outstanding symposium on rare and precious metals.

The morning session was opened by R. S.

DEAN, who pointed out that our shortage in certain of the so-called "rare metals" could be rectified by metallurgical ingenuity, for most of these metals occur in lean deposits somewhere in the United States. In South Dakota, for example, occur pegmatites with small, but workable, concentrations of tin, lithium, tantalum, beryllium and other metals. Some have been mined sporadically and can be worked again.

Substitutes for such of the rare metals as have become rarer in war times were discussed by W. P. SYKES. Silver is a popular substitute for tin in solders and other uses. This subject was further pursued by ROBERT H. LEACH and JOHN L. CHRISTIE who described also the adoption of silver alloys for aircraft bearings and for the construction of various kinds of electrical equipment. A. J. PHILLIPS recommended the substitution of a group of lead-tin-bismuth alloys for the binary tin-lead solders. Solder was an argumentative subject, and it was pointed out that the chief difficulty in applying most of the substitute solders derives from their long freezing range, that leads to hot cracking from dimensional changes in the work while cooling. A fascinating study of the tarnishing characteristics of silver was reported by W. E. CAMPBELL. It is a matter of much importance to contacts in telephone equipment. The only alloy addition known that materially reduces the tarnishing of silver is palladium.

In the afternoon K. K. DARROW delighted a full house with one of his deservedly famous talks on transmutation of elements. He pointed out that although all the chemical elements have been produced by atom bombardment — and isotopes, as well, to a total of over 300 — only helium and mercury have been made in quantities sufficiently large to obtain a spectrographic indication. Oddly, the mercury is produced from gold rather than gold from mercury as the alchemists would have had it! Although there is little prospect of producing commercial quantities of any metal by atom bombardment, the radioactive isotopes of metals produced in this way are already of use to metallurgists in radiography and certain research applications.

F. R. HENSEL then described dozens of important applications of rare metals in the electrical industry, for resistors, bi-metals, contacts, magnets, bearings, springs, electron tube parts. Almost every obtainable metal was mentioned. The uses of powder metals were also interestingly reviewed by C. G. GOETZEL. Somewhat unusual in a metallurgical meeting was

the talk by M. B. VILENSKY who described the applications of rare metals in the glass industry. Platinum and its alloys are extensively used in handling equipment and many metals and their salts are employed for coloring. The symposium was brought to its conclusion with a talk by H. E. STAUSS on time-to-fracture tests on platinum and certain of its alloys.

Constitutional Diagrams — Institute of Metals' program also included reports on three constitutional studies and three subjects of theoretical interest. Phase diagrams of the systems magnesium-tin and magnesium-lead were presented by GEOFFREY V. RAYNOR, of the system copper-iron-silicon by A. G. H. ANDERSEN and A. W. KINGSBURY, and of the system lead-antimony by W. S. PELLINI and F. N. RHINES. The first of these was in reality a critical comparison of the X-ray diffraction and metallographic techniques for determining solid solubility limits (the author favors the metallographic method), the second was an application of an X-ray diffraction technique previously developed by the authors, while the third paper dealt with a rupture-at-liquation method for determining solidus boundaries.

Brass — The physical properties of β' brass are of special theoretical interest inasmuch as β' is well known as a super-lattice modification of β brass and at the same time is a material of some technical usefulness. C. S. SMITH demonstrated that the hardness of β' brass developed by quenching from a temperature of complete disorder is quickly lost upon standing at room temperature. If the material is quenched from a temperature of partial ordering, however, the hardness is retained for many days. It is suggested that the change from disorder to order ("ordering") occurs at the upper limit of the β' range, at least in part and at long range, and that this does not so easily revert to short-range ordering at room temperature as does the completely random structure of β brass.

CLARENCE ZENER examined the damping characteristics of an α brass single crystal from which he deduced the presence of some unidentifiable inhomogeneities in it. In discussion, H. L. BURGHOFF pointed out that the well-known lineage structure found in cast brass crystals might be the inhomogeneity sought.

Aluminum-Silicon — The third of the theoretical papers, by L. K. JETTER and ROBERT F. MEHL, dealt with the measurement of the rate of precipitation of silicon in aluminum-silicon alloys by a highly sensitive dilatometric tech-

nique. Both increasing solute concentration and a more rapid rate of quench accelerate precipitation. The applicability of nucleation theory to this process was discussed.

War Production Meetings

Because of the off-the-record nature of the War Production Meetings only generalities may be reported. For this the reporter is thankful, because the discussions covered a tremendous range and a mass of detail not abstractable in the few lines available. Suffice it to say, therefore, that the meetings devoted to aluminum and magnesium were mainly given over to short courses in the handling and fabrication of these metals. The bulk of this material is available in reference books and trade literature.

Powder Metallurgy — This program, though designed as a predominantly non-ferrous session, could not be diverted from the subject of iron powder. Somewhat facetiously the keynote of this meeting was sounded from the audience in the comment, "What we need is a good five-cent iron powder." It was made clear that current thought is mainly in the direction of producing a better and cheaper electrolytic iron powder in large quantities, to replace missing imports from Sweden and to provide for a rapidly expanding demand.

The meetings on tin and on secondary metals were closely related, inasmuch as both dealt with means for conserving tin and for using tin-bearing scrap in the most economical ways. With the conservation measures now in effect the tin supply is adequate, but no relaxation in these measures can be permitted. It is urged that non-ferrous foundries use the lower purity secondary alloys wherever at all possible in order to utilize the relatively large stock of secondary lead-bearing tin alloys; this applies in particular to bronzes where the limits on the lead content might well be raised. Non-ferrous scrap now being collected can readily be put into brass (and so-called "bronze") alloy ingots with a tin-lead ratio of one; shortages may be expected if alloys with lower lead are demanded. In many places the higher lead alloys serve excellently. Another point worth remembering is that in substituting manganese bronze for other alloys requiring a larger amount of high grade No. 1 copper scrap it is very often unnecessary to strive for the high physical properties commonly associated with the best of the manganese bronzes.

Recruiting and Training of Inspectors

By Leroy L. Wyman

THE FUNDAMENTAL THEME of the entire program on recruiting, training, and handling of inspectors of metallurgical material was appropriately described in a few fore-words to the effect that production of large quantities of war materials without adequate quality control will inevitably result in great waste, and inasmuch as quality control is a personal thing, it must be assured that further waste is not hazarded by utilizing improper personnel and personnel training methods.

Recruiting of inspectors today is primarily the function of the Civil Service Commission, since most of them are Civil Service employees. However, the several war agencies, including the Ordnance Department, provide or suggest potential personnel to the Commission. After investigation and examination, the Civil Service Commission approves or rejects the applicants for this work, the successful ones being employed and trained for the particular position awaiting them.

Due to existing conditions it must be realized that there are now very few people having adequate education and training available for this work, consequently this personnel must be chosen on the basis of a reasonably good educational background coupled with an inherent alertness, clear eyesight, and ability to absorb the training methods now employed. Furthermore, the matter of permanence or tenure for the duration becomes a factor of considerable importance; thus inspectors must be drawn from the available women and older men.

Experience already gained in training inspectors of metallurgical processes and materials has definitely shown that it is not feasible to take these trainees — who represent an average cross section of American citizens — and train them solely in inspection methods and interpretation. The weakness in such procedure becomes self-evident because an individual so trained is working blindly and cannot intelligently apply the testing methods or interpret the results of his observations, nor can he meet the responsibilities inherent in his position. Such a condition would waste both man power and material and can only be corrected by adequate basic training.

For inspectors on this type of work it is essential that they be given some fundamental training in the structure and behavior of metals and alloys from both the theoretical and practical standpoints. After having learned these fundamentals of metallurgy, the trainee can more readily understand the reasons for the various tests employed and also realize the sources of trouble which lead to rejected material and the proper corrective measures to be suggested.

The actual program for this kind of training is being worked out in several different ways, one of the most prominent being the "ESMDT Training Courses" presented as evening classes at many of our colleges and universities by the cooperative effort of the U. S. Department of Education, the school staff and plant, frequently supplemented by an instructing staff consisting of industrial experts.

A highly successful method of training is known as the "cooperative plan", in which the trainee is given the more practical aspects of the training program on the job, in the plant, by combining practice and lecture periods, while the formal and theoretical background is provided in the facilities of neighboring technical colleges during evening class sessions.

Textual material for presentation to classes of this type presents a major problem, for as was repeatedly emphasized, these inspectors must be trained in a minimum of time and the total training must adequately cover all of the important factors which would ordinarily be spread out through several years of normal schooling. Some special text-books have been prepared with this type of training in mind. Existing texts dealing with the metallurgical fundamentals are usually too exhaustive and require too much supplementary information.

This subject matter must likewise be presented in a manner which is not only interesting, but the correlation with the practical applications must be repeatedly emphasized. Experience has shown that presentations of this kind can best be made by an instructor who is or has been actively engaged in the practice of the metallurgical profession.

The use of women as inspectors is increasing at a rapid rate, not only because of the greater number of the fair sex that wish to do this work, but also because it has been found



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that when sufficient care is taken in the training program to present the subject matter in such manner as will enable the women to get it, the results are surprisingly good. Teachers must fully realize that women trainees are quite unfamiliar with technical methods and terminology and care must be taken to provide for this deficiency adequately. Ordinarily, women do not have as much aptitude for this kind of work as do the men, and those who do, have it in an undeveloped state, because they have lacked the opportunity. However, women with an inherent aptitude are more conscious of the fact that they are quite lacking in knowledge of technical matters, and are therefore more susceptible to training.

Those positions where the work is highly repetitive prove quite favorable to women. Studies of job fatigue of men versus women on repetitive work have shown that women will retain jobs of this type up to nine times as long as a man! For such reasons women are relied upon for gaging operations and similar forms of visual and dimensional inspection.

The handling of large staffs of inspectors presents a major problem in organization because of the wide diversity of the kinds of work which must be performed. This is handled with the greatest efficiency by having the

inspection force divided into sections, each specializing in a particular type of work and supervised by an expert in this particular field. An inspection staff organized in this manner not only works with greater efficiency, but also permits of out-of-plant inspection in sub-contractors' factories with greater assurance of satisfaction.

In all of the discussion concerning the inspection personnel and its training, the question of the permissible latitude of inspection was repeatedly brought forth. This was quite adequately answered in terms of service performance, for only that latitude of deviation from the "perfect" may be utilized which will still guarantee that the accepted product will give satisfactory service performance.

Probably more latitude is used in sampling than in variation from a specified standard, for it is in the former the unconscious errors may be made, resulting in dangerously large amounts of poor material being accepted because the sampling methods were too meagre to insure the reasonable probability that faulty material will be found and rejected. In either instance of the use of the permissible latitude, the important factor is the availability of a sufficient quantity of war products having ample quality to do the job that lies ahead.

Points of Theoretical Interest

By Malcolm F. Hawkes

FEWER TECHNICAL PAPERS and added emphasis on practical considerations at the recent National Metal Congress in Cleveland attested to the fact that most metallurgists have been at the grim business of winning the war of production for the past year. However, those who were able to attend at least a few Φ or A.I.M.E. sessions found that excellent theoretical research has not been stifled entirely. Evidence for this fact could be drawn, for example, from the Φ session on molybdenum steels. Here the need was established for correlation of data on the several crystallographic processes governing austenite transformation and the hardenability of alloy steels. A start on this problem was made in a series of three papers on related phenomena in molybdenum steels.

In the first of these, BOWMAN, PARKE and HERZIG point out that knowledge of the distribution of alloying elements in alloy steels between ferrite and carbide is of prime importance when considering the rate of growth of pearlite and, hence, hardenability. As pointed out in discussion, residue analysis methods used heretofore for this purpose have not yielded data reliable enough. Therefore the new method suggested by the authors will be of interest to workers in this field. They have demonstrated that the lattice parameter of ferrite varies appreciably with concentration of dissolved molybdenum. This effect is great enough that X-ray diffraction measurements of ferrite in pearlite will serve to determine the concentration of molybdenum in this constituent; molybdenum in the carbide layers is obtained by difference.

In another paper of this series, HAM, PARKE and HERZIG have determined the effect of molybdenum on the rate of diffusion of carbon in austenite. Although the effects of nickel and manganese have been determined before, this is the first work of this nature that has studied a strong carbide-forming element. The diffusion coefficient was shown to vary with temperature in such a way that molybdenum increases the rate of carbon diffusion at temperatures above 2000° F., and decreases it at lower temperatures. On a simple theoretical basis, the authors show that the calculated decrease in diffusion rate does not explain the pronounced effect of molybdenum in decreasing

the rate of formation of pearlite (or its equivalent, increasing hardenability). As was brought out in discussion, however, the precise relation between the rates of diffusion and growth is probably extremely complicated.

With the third of these papers, BLANCHARD, PARKE and HERZIG extended their reports on S-curves for molybdenum steels into the range of hyper-eutectoid carbon contents. They have added to the evidence that two different nucleation and growth processes are responsible for the formation of pearlite and bainite, respectively. Molybdenum suppresses the rate of the former process to a much greater extent than the latter, and this surprising effect produces the "second knee" in S-curves for molybdenum steels. Pearlite spacing was shown to increase with molybdenum content. One commentator said that this usually appeared to be true for alloying elements that increase hardenability, while the reverse is true for cobalt (which decreases hardenability by increasing the rate of formation of pearlite).

Austenite Formation — Another Φ session threw light on the very fundamentals of hardenability, namely, the mechanism of formation of austenite, its initial grain size, and its homogeneity. In two papers, DIGGES and ROSENBERG presented data on austenite formation and grain size in 0.50% carbon steels and a high purity alloy of similar composition. They found that pronounced grain growth on heating between A_{c1} and A_{c3} overshadowed the influence of nucleation rate on austenite grain size above A_{c3} , but that the initial structure before heating had little influence. This grain size appeared to be smaller in the pure alloy after slow rates of heating, while rate had little effect in the commercial steels. ROBERTS and MEHL also presented quantitative data on rates of formation of austenite at constant temperature. Summarized in a plot analogous to the S-curve, the data show that austenite is formed at a continually increasing rate as the temperature increases above A_1 but that much longer times may be required to eliminate residual carbides and carbon concentration gradients than one might expect. Finely dispersed initial structures led to faster rates of formation of austenite and finer initial austenite grain size. Quantitative data on relative rates of nucleation and growth were used successfully to predict the fracture grain size of austenite.

Transformation of Highly Alloyed Austenite

The session on toolsteels produced much data to supplement our growing knowledge of the behavior of austenite at subcritical temperatures, and at the same time, it provided a wealth of practical information necessary for the proper heat treatment of tools. PAYSON and KLEIN presented a collection of S-curves for toolsteels ranging from the plain carbon grades to 18-4-1 high speed steel. (It will be noted with pleasure that the papers in this session ushered in the extensive use curves prepared in such a way that they depict accurately the complete story on the temperature range for martensite formation. However, the number of terms used to designate various types and shapes of "S-curves" is increasing in direct proportion to the number of papers published!) The authors demonstrate that, before tempering a quenched toolsteel, it should be cooled to a temperature low enough to get complete transformation of austenite to martensite (or at least as low as possible without cracking). High heat treating temperatures were shown to lower the temperatures required for transformation to martensite.

A spirited discussion arose between adherents of this paper, which reported about 20% austenite retained at room temperature, and those of GORDON, COHEN and ROSE, who reported about 2% retained. The last group of authors made an exhaustive study of austenite decomposition in "18-4-1" and also "6-6-2" high speed steels subjected to a variety of subcritical treatments. These steels behave very much alike; likewise the general nature of their "S-curves" agreed with the other investigators'.

Many interesting behaviors were found on various interrupted treatments. As hot quenching temperatures are raised above 1100° F., the danger of precipitating carbides or of forming "pearlite" is continually increased. Hot quenching and holding for any length of time in the range 1100 to 700° F. decomposes no austenite. On subsequent cooling, however, if the holding temperature is within 1000 to 1100° F., a split transformation occurs — that is, some bainite forms at about 500° F., before the martensite reaction occurs. Long holding times and higher holding temperatures within the 1000-1100° F. range increase both the temperature at which this bainite starts to form and the amount formed, and produce just the opposite effects on the martensite reaction. Holding at

constant temperature in the range where any amount less than about 30% martensite is formed causes the gradual formation, within an hour or so, of 2 or 3% bainite in the regions adjacent to martensite plates; longer holding produces a somewhat faster reaction to bainite throughout all the untransformed austenite. However, in all temperature ranges the bainite reaction eventually slows down. The maximum amount of bainite that can be formed under any conditions within reasonable time is about 55% — this is at about 500° F., which is the temperature of the second knee. This knowledge of how to exert wide control over the various constituents formed during heat treatment led to many queries as to corresponding mechanical properties. No data are yet available, but are expected in the near future.

ZMESKAL and COHEN studied the tempering of high carbon, high chromium steels with particular emphasis on the kinetics of decomposition of the large amounts of austenite retained on quenching. In the range of cooling rates producing martensite plus retained austenite, the proportion of the latter increased as the rate of cool from the hardening temperature decreased and also as the hardening temperature increased. Rates of decomposition of austenite during various isothermal tempering treatments were depicted on curves analogous to ordinary S-curves, which show extremely slow rates below 300° F., increasing to a maximum at 500 to 600° F., and then decreasing to extremely slow rates again at 700 to 800° F. Above this range, the rates gradually increase and are almost too fast to measure at 1200° F. Such rates of transformation of retained austenite are decreased by increasing the hardening temperature, but are not affected materially by rate of quench from that temperature. Holding at tempering temperatures for longer and longer times, even though those times are too short for any decomposition of the retained austenite, "conditions" that austenite for faster transformation on subsequent cooling — that is, causes an increased tendency for part of it to transform to bainite at 500 to 600° F. instead of to martensite at 300° F. and below.

Hardenability Test — That the technique of testing for hardenability is still of great interest to ASMembers was shown by the shortage of empty seats at sessions on this subject. In two papers on the Jominy test, HILL showed that it is quite necessary to avoid scaling the end of the specimen in order to get reproducible curves.

but that other minor test conditions exert little influence. He suggests a method by which the hardenability of large numbers of steels can be compared simply and economically. It makes use of numbers representing intercepts and slopes of three straight lines which approximate the three portions of the Jominy curve, its beginning, the steep part, and the tail-off.

In a paper on the effect of individual alloying elements on the hardenability of hyper-eutectoid steels, AUSTIN, VAN NOTE and PRATER corroborated, in general, the findings of GROSSMANN. However, instead of finding the diameter of hardenable bars to increase as a straight line function of per cent of alloying element in the low ranges, they find this increase slopes off from the very start. In contrast to GROSSMANN, they find chromium to be somewhat more effective than manganese.

Using the GROSSMANN method for calculat-

ing hardenability from composition, JACKSON and LUTHER showed in a paper presented before the A.I.M.E. that weldability of carbon and low alloy steels can likewise be predicted. They establish a correlation between calculating critical diameter and the load observed at failure of many V-notched slow-bend specimens

Another method of calculating a mechanical property from composition was presented by WALTERS to the Iron and Steel Division, A.I.M.E. His studies on the tensile strength of normalized medium carbon alloy steels have resulted in factors (similar to GROSSMANN's hardenability factors) to be multiplied by a base tensile strength in order to calculate the tensile strength of a steel from its composition. At another A.I.M.E. session, HALLEY showed that the effect of tin in steel can be estimated in the same type of calculation by assuming its effect to be similar to phosphorus but only one-fifth

as potent. In this timely paper on the effect of tin on the strength and ductility of plain carbon steel, some metallographic evidence is presented for grain boundary precipitation in steels high in tin.

AUSTIN has isolated the effects of several other alloying elements by studying the hardness and response to heat treatment of high purity iron binary alloys. His paper, read before the A.I.M.E., confirms experimentally the generally accepted view that lattice distortion by solid solution causes increased strength. Evidence is also presented to show that the greater the difference in atomic radius between the added element and alpha iron the greater the hardening effect will be.

Iron-Manganese Alloys—TROIANO and MCGURK presented the results of a careful study on the iron-rich portion




of the iron-manganese binary phase diagram. They showed that the $\gamma \rightarrow \epsilon$ reaction and the $\gamma \rightarrow \alpha$ reaction usually observed are reactions of the austenite \rightarrow martensite type and the products obtained are supersaturated with respect to manganese. Painstaking annealing and working operations were used to induce the $\gamma \rightarrow \alpha$ transformation to occur under "equilibrium" conditions, and when determined in this way, the limits of the α and the $\alpha + \gamma$ fields were found to lie at lower manganese contents than previously reported. In discussion, it was brought out that, for this same reason, many accepted phase diagrams for metal systems may show solid solubility limits that are much too high.

The martensite type of reaction was also discussed by SYKES in a paper on the Ar range in iron-cobalt-tungsten alloys. An alloy containing 30% Co, 17% W, 53% Fe was shown to decompose from γ to α on cooling, starting at 975 and ending at 660° F. Additions of chromium depressed the range considerably.

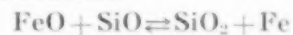
Physical Chemistry of Steel Making

Those interested primarily in the rapidly advancing science of steelmaking were served a treat at the Campbell Memorial Lecture in which JOHN CHIPMAN summarized in plain words his extensive studies on the thermodynamics of liquid steels and slags. Ordinarily the Memorial Lecture is summarized in *Metal Progress*, but since it will be printed in full in *Transactions* next month, the full flavor of its fascination should there be tasted.

Parts of this work were expanded elsewhere, such as at the A.I.M.E. session on physical chemistry of steelmaking. Here TAYLOR and CHIPMAN described the results of slag-metal experiments in a rotating induction furnace which prevented reaction with the crucible walls. In this way they were able to extend measurements of oxygen solubility in steel and FeO activity in slag into systems with very low lime-silica ratios. Activity measurements deviating from Raoult's law were explained by the assumption of a double molecule $(2\text{CaO} \cdot \text{SiO}_2)_2$ and a compound $\text{CaO} \cdot \text{Fe}_3\text{O}_4$. A new method for representing the solubility of oxygen in liquid steel under these three component slags was presented, wherein iso-oxygen lines are plotted against a simple basicity ratio. Usually a ternary diagram has been used. Their improved liquid metal sampling device should also be noted by those doing similar work. CHIPMAN

and GRANT also offered a new experimental technique to the  steelmaking session for determining heats of reaction at steelmaking temperatures. Using an induction furnace as a high temperature calorimeter, they established the heat of solution of liquid silicon in liquid iron at 1600° C. to be 29,000 calories per gram-atom of silicon.

Other A.I.M.E. sessions brought out further interesting work in this field. ZAPFFE and STYS have studied the silicon-oxygen equilibrium in liquid iron by controlling the activity of oxygen through the use of a $\text{H}:\text{H}_2\text{O}$ atmosphere of known oxygen pressure in equilibrium with the liquid iron. After the silicon-oxygen equilibrium was established the metal was rapidly quenched and analyzed for silicon. It was shown that neither total oxygen concentration nor silicon concentration of the metal can be used as terms in a true equilibrium constant for this system. Instead of using arbitrary "activity coefficients", the authors show their data will fit an equilibrium constant expression based on the reaction



and then present further evidence supporting the existence of the hypothetical compound SiO.

In another paper ZAPFFE discussed the causes of bleeding in killed steels and irons (this refers to the late rising or even liquid exudation of solidifying castings in cases when the carbon-oxygen reaction plays no part). Hydrogen, which may be picked up from moisture, was shown to be the chief offender, because it can dissolve in large amounts in deoxidized liquid steels but is only slightly soluble in delta ferrite. A spirited discussion arose over whether or not accessory bubble formation was necessary to initiate the violent hydrogen evolution, and over the use of alloying elements to prevent bleeding. Steels which can be made to freeze directly to austenite are less troublesome because austenite has a much higher solubility than delta ferrite for hydrogen. In like manner high chromium steels made with high nitrogen ferrochromium were shown to be subject to nitrogen bleeding, which can be eliminated by a nitrogen stabilizer such as titanium.

In another timely paper, direct reduction of iron ore was treated by UBY and LOXG from the all-important standpoint of rate of reaction. They reduced magnetite concentrates with pure hydrogen at 1308° F., the process originating at the particle surface and proceeding inward. The variation of their

(Continued on page 931)

Necessity for remelting reclaimed tin cans means that the steel metallurgist must know something about iron-tin alloys. Likewise the heat treater, for tin apparently concentrates on scaled steel surfaces. This recent article has been prepared for the next edition of the *Metals Handbook*

Constitution of the Iron-Tin Alloys

THE COMPLETE CONSTITUTION of the iron-tin alloys has not yet been definitely established, although the diagram shown in Fig. 1 has been drawn to represent the present state of knowledge based mainly on the work of Edwards and Preece¹, with modifications and additions by Ehret and Westgren², Jones and Hoare³, Wever and Reinecken⁴, and recent work by Ehret and Gurinsky (see Appendix, page 904).

As tin is added to iron, the liquidus *AB* in Fig. 1 falls rapidly from the melting point of iron, 1535° C. (2795° F.), to 1110° C. (2030° F.) at 51% Sn. The alloy solidifying over this range of composition consists of α solid solution of tin in iron; extent of solubility varies with the temperature following the line *HI*, the upper portion of which has not been definitely determined. The line *BC* is horizontal from 51 to 80% Sn. The dotted convex line *BC* is drawn to represent an undetermined area in the liquidus, in which two liquid phases exist. Alloys of from 51 to 80% Sn begin to deposit solid solution of composition *H* when cooled to 1110° C. (horizontal line *BC*) thus increasing the quantity of the second liquid of composition *C*. As cooling proceeds, crystals of *III* composition are formed from liquid *CD*, thus changing its composition until it corresponds with *D* when the temperature falls to line *ILD*.

The thermal effect indicated by line *ILD*, taking place at 900° C. (1652° F.) in all alloys of 17.5 to 96% Sn, is not very marked. For alloys approximating 17.5 to 96% Sn, a peritectic reaction is indicated at temperature *L*, 900° C. (1652° F.) From 17.5 to 51% Sn α solid solution reacts with the liquid to form a con-

stituent thought to be the compound Fe_2Sn . From 51 to 96% Sn the same compound is formed plus a Sn-rich liquid. At temperature *O* (800° C. or 1472° F.) these components react peritectically to form what is believed to be FeSn . Between approximately 51 and 68% Sn and from 800° to 760° C. (1472° to 1400° F.), area *MOPN*, two phases are thought to exist consisting of $\text{Fe}_2\text{Sn}(?)$ and $\text{FeSn}(?)$. Within the composition range from 68 up to 97 to 99% Sn and a temperature range of 800° to 496° C. (1472° to 925° F.),

designated by area *OEFSQ* the compound $\text{FeSn}(?)$ is believed to be formed from the $\text{Fe}_2\text{Sn}(?)$ + liquid, thus resulting in $\text{FeSn}(?)$ + Sn-rich liquid. Below 496° C. (925° F.) the compounds and constituents formed have been more definitely established and are as shown in the diagram.

For convenient reference a modified form of a chart by Hedges and Homer⁵ is shown in Table I, page 900. The γ region, as marked off by the broken lines in Fig. 1, indicates that with tin present the γ state is limited and the position of the thermal critical points will vary with the percentage of tin. Although knowledge is very limited concerning this part of the diagram, it is likely that if over 1.9% of tin is present, γ iron is no longer formed. With a given tin

Fig. 1 — Iron-Tin Equilibrium Diagram of Edwards-Preece, Modified to Harmonize the Most Reliable Researches to Date

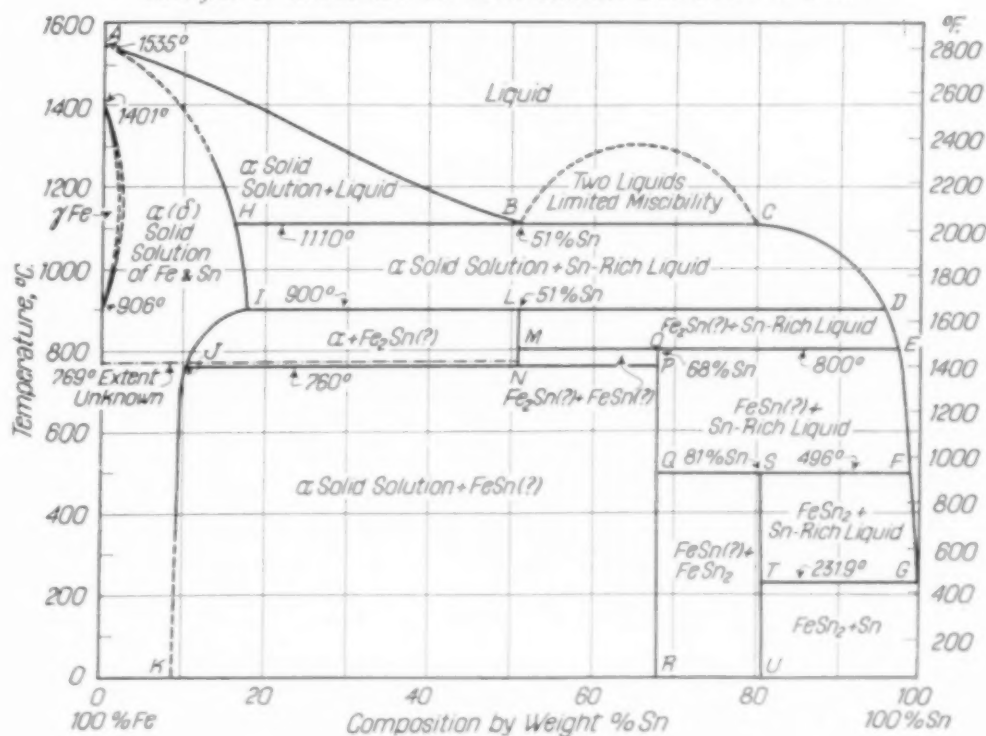


Table I—Principal Data on Fe-Sn Diagram

TEMPERATURE		NATURE OF TRANSFORMATION	COMPOSITION (% TIN)
°C	°F		
1110	2030	Liquid B \rightleftharpoons Liquid C + α	51 to 80
900	1652	Peritectic; Sn-rich Liquid + $\alpha \rightleftharpoons$ Fe ₂ Sn(?)	17.5 to 96
800	1472	Peritectic; Sn-rich Liquid + Fe ₂ Sn(?) \rightleftharpoons FeSn(?)	51 to 98
760	1400	Fe ₂ Sn(?) \rightleftharpoons FeSn(?) + α	10 to 68
496	925	Peritectic; Sn-rich Liquid + FeSn(?) \rightleftharpoons FeSn ₂	68 to 99.5
232	450	Sn-rich Liquid \rightleftharpoons Sn + FeSn ₂	80.96 to 100
13.2	55.8	White Tin \rightleftharpoons Grey Tin*	100
1401	2554	{Region of γ state in iron marked off as an approximation.	
906	1663	{Outside this area, γ iron supposedly does not exist.	
769	1416	Magnetic change of iron not appreciably affected by Sn.	

content, the positions of the transition points fluctuate with variation of carbon even when present in very small amounts. Thus it would be expected that the position of thermal critical points in steel containing small percentages of tin would likely vary considerably, depending not only on the tin but also on the carbon content.

Historical Development

For those interested in the details of development of the iron-tin constitution diagram, its history is here briefly discussed, considerable dependence being placed on the writings of Hansen⁷.

Early investigations indicated the existence of numerous intermetallic compounds, such as Fe₂Sn (Bergmann¹⁰ and also Berthier¹¹), Fe₃Sn (Lassaigne¹²), FeSn (Deville and Caron¹³), Fe₂Sn₃ (Berthier¹¹), FeSn₂ (Nollner¹⁴), FeSn₃ (Spencer¹⁵), and FeSn₄ or FeSn₅ (Rammelsberg¹⁶). Headen¹⁷ indicated that besides Fe₂Sn, FeSn and FeSn₂ the compounds Fe₂Sn₃, Fe₂Sn₄ and Fe₂Sn₅ were formed. Later work indicated that with the exception of FeSn, there is no certainty of the chemical entity of any of these¹⁸.

Isaac and Tammann¹⁹ conducted the first systematic thermal and microscopic study of this binary alloy system and Fig. 2 shows their diagram. On the basis of the thermal arrest noted at 1140° C. (2084° F.), they assumed the solubility of iron in tin to be about 19% at all lower temperatures. Since with alloys containing 0 to 90% Sn, two fluid layers were found to separate prior to solidification, they concluded that a region of incomplete miscibility existed in the liquid state. They assumed that the solid solution, which first separated, reacted at 893° C. (1639° F.) with the liquid (96%

Sn) and formed a compound. It is designated as Fe₂Sn₃ in the diagram; due to marked segregation encountered in many of their alloys, they were dubious of its formula. The arrest at 780° C. (1436° F.) they viewed as a polymorphic transformation of this compound which exhibited a fairly significant maximum at 40% Sn (Fe₂Sn would contain 41.47% Sn). At 496° C. (925° F.) they supposed that either another polymorphic transformation of the compound occurred or that the compound reacted with the tin-rich liquid to

tion. They did not investigate the possible influence of tin on the polymorphic transformation point of iron, but it was suggested that the transformation temperature of α to γ iron might rise with increasing tin. They found no variation in the magnetic transformation point of iron containing up to 20% Sn.

Wever and Reinecken⁴ arrived at quite different conclusions about 20 years later, although their diagram (Fig. 3) is quite similar in many respects to that of Isaac-Tammann. They denied the existence of partial miscibility in the liquid state since they found no segregation if the melt was rapidly stirred and quenched. [However, Ruer-Kuschmann²⁰ prepared an alloy containing 70% Sn from pure tin and electrolytic iron using a porcelain tube to prevent carbon absorption and an argon atmosphere to avoid oxidation or other contamination. This alloy they heated to 1400° C. (2552° F.), afterward stirred at 1300° C. (2372° F.), and allowed it to cool in air. A sharp separation of two layers resulted and

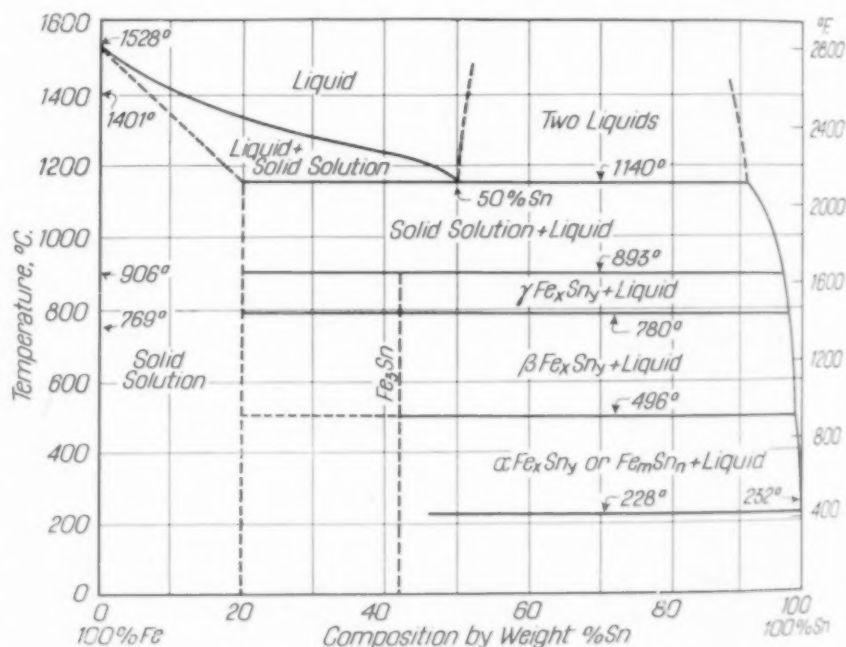


Fig. 2 — 1907 Diagram of Isaac and Tammann, the First Based on Systematic Thermal and Microscopic Study

form a compound still richer in tin (designated as Fe₂Sn₃ in the diagram, but perhaps FeSn₂ containing 80.96% Sn). The remainder of the liquid solidified at approximately 228° C. (442° F.), and they surmised that a eutectic might exist, which, if FeSn₂ was actually present, should reach equilibrium only at this concentra-

each layer contained numerous tin-rich globules. From this they concluded that stratification resulted when the alloy was in the molten condition.]

Considering alloys in the range of 18 to 48% Sn, Wever and Reinecken concluded that the compound Fe₂Sn formed at 1132° C. (2070° F.)

through a peritectic reaction. They found evidence for the assumption that part of the primary compound FeSn in alloys of higher content than 41.47% Sn was converted at 890° C. (1634° F.) to a mixture of FeSn₂ with Sn, and that the FeSn crystals remaining decomposed at a slightly lower temperature into iron-rich solid solution and FeSn₂. They concluded that FeSn rather than FeSn₂ underwent polymorphic changes at 780°, 755°, and 490° C. (1436°, 1391°, and 914° F.), and that the melt remaining was practically pure tin. They found the solubility of tin in iron at 1132° C. (2070° F.) to be about 18%, decreasing with lowering temperature, but the exact saturation limits were not determined because of the effect of carbon on the solubility of tin at the lower temperatures. An alloy with 12.4% Sn was found to retain small quantities of FeSn₂ after long heating and slow cooling, and these investigators apparently believed that this tin-rich compound was FeSn₂. According to Hansen⁷ their results did not clearly show that the iron-rich compound, which he believed was probably FeSn, decomposes at 890° C. (1634° F.) into the α phase and FeSn₂.

Wever and Reinecken, using alloys with about 0.015% C, conducted some experiments on the effect of small percentages of tin on the transformation points of iron. With 1% Sn the $\alpha \rightleftharpoons \gamma$ transformation

point was raised about 40° C. (104° F.) and the $\gamma \rightleftharpoons \delta$ transformation lowered about 140° C. (284° F.). With tin above about 1.9% the transition point $\gamma \rightleftharpoons \delta$ appeared to be missing. Therefore they have designated by broken lines the area of tin concentration and temperature range where the γ transition occurs. Outside this area no transformation occurs, since α and δ are now identical. Hansen⁷ also states that carbon in the iron-tin alloys has a considerable effect on the position of the transition points. For example an alloy with 1% Sn and 0.04% C has a $\gamma \rightleftharpoons \delta$ transition 120° C. higher than if carbon is 0.015%. Hansen also indicates that

a carbon-free alloy has a γ region narrower than shown in Fig. 3. Wever and Reinecken checked Isaac and Tammann, that the magnetic transformation point of iron is not affected by the presence of tin.

Edwards and Preece¹ developed a phase diagram in 1931 using thermal and microscopic methods, which is in most essentials the same as Fig. 1. The main differences are as follows:

(a) Figure 1 shows the solubility of Sn in Fe increasing along the line AHI to 900° C. (1652° F.) while Edwards and Preece show a continuing increase in solubility to 760° C. (1400° F.), with a maximum solubility of 18% at 760° C. (1400° F.) rather than 17.5% at 900° C. (1652° F.) Accordingly, at 760° C. (1400° F.) the solubility is shown as about 10% as found by Ehret and Westgren² and later confirmed by Ehret and Gurinsky (See appendix) rather than the 18% shown by Edwards and Preece.

(b) Also in Fig. 1 we have affixed a (?) after all compounds except FeSn₂ to indicate some uncertainty as to their being definite intermetallic compounds. Edwards and Preece disagreed in many respects with the conclusions of Wever and Reinecken; the more recent investigators quenched samples for their microscopic examination from the various regions after suitable heat treatment. They determined that a region of limited miscibility was present in the liquid state, which was also confirmed by Bannister¹⁰. These investigators also questioned the existence of the compound FeSn as surmised by Wever and Reinecken, and also

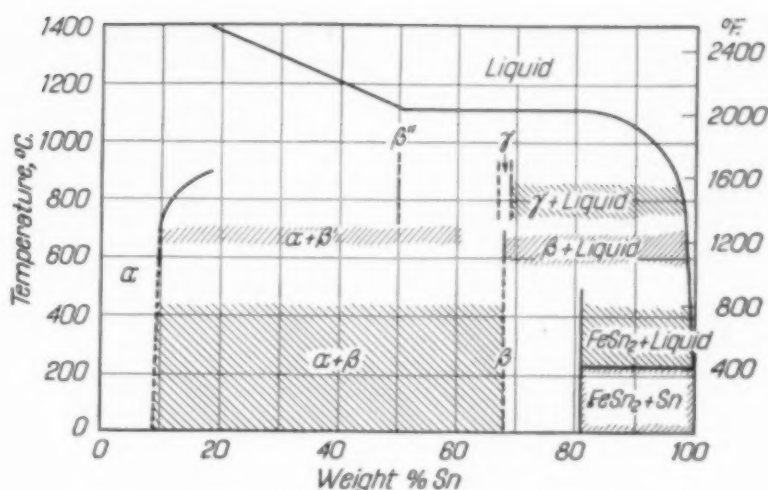


Fig. 4 — Results of X-Ray Diffraction Studies by Ehret and Westgren on Quenched and Powdered Alloys

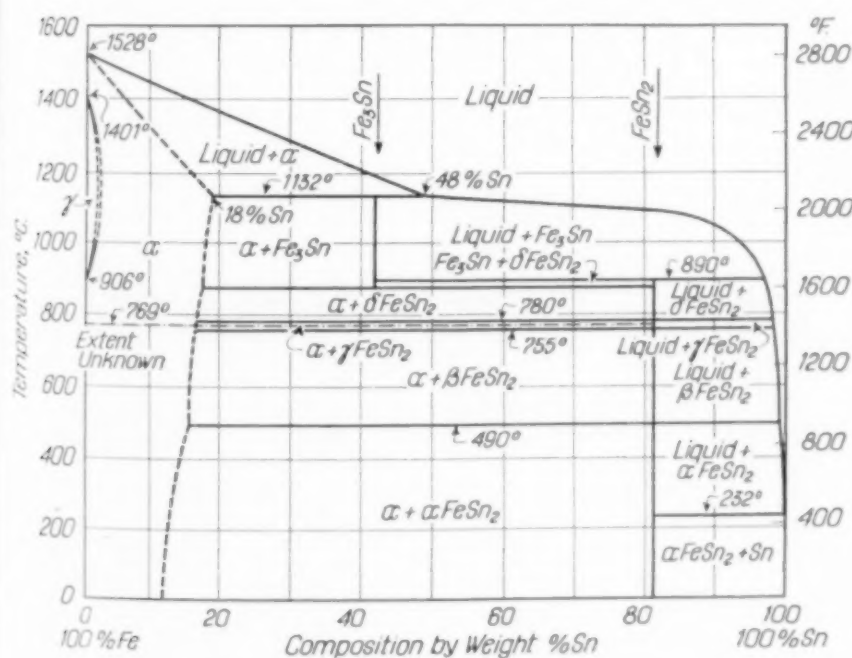


Fig. 3 — 1925 Diagram of Wever and Reinecken. They were unable to determine the limits of the alpha solid solution

considered that a compound Fe_3Sn was stable between 760° and 900°C . (1400° and 1652°F .) Edwards and Preece also found that the compound FeSn was stable from 800°C . (1472°F .) to room temperature, and that the compound FeSn_2 existed only below 496°C . (925°F .)

Ehret and Westgren² made an extensive X-ray analysis in 1933 of the iron-tin system, using the powder diffraction method. Their diagram, shown in Fig. 4, agrees fairly closely with Edwards and Preece's. The former indicated the presence of β' and γ phases, stable at high temperatures, which were not indicated by Edwards and Preece. The constitution below 500°C . (932°F .) checks well with the latter's findings, and therefore this part of the diagram seems well established, although Ehret and Westgren show FeSn as β phase rather than as a definite compound. They concluded that the region of the diagram from 10 to 100% Sn and above 496°C . (925°F .) required further investigation, and in this conclusion Jones and Hoare³ appear to agree. Some specific results of Ehret and Westgren's X-ray work are noted below:

1. The solubility of tin in iron (α phase) is 9.8% at 680°C . (1256°F .), and 18.8% at 900°C . (1652°F .)

2. The β phase has a hexagonal lattice and a very restricted region of homogeneity; composition corresponds to the formula FeSn , the unit cell contains three groups of FeSn .

3. The β' phase was found in alloys with 27, 39, 48, and 59% tin after quenching. The structure could not be defined; some evidence indicated a mixture of two phases but other evidence did not support this conclusion.

4. The β'' phase was found in alloys with 27, 39, and 48% Sn, quenched from 860°C . (1580°F .) It had a restricted region of homogeneity, was hexagonal and corresponded to the composition Fe_3Sn with unit cells containing two Fe_3Sn groups. It was also present in alloys of 27 and 40% Sn, quenched from 950°C . (1742°F .)

5. The γ phase was found in alloys with 27, 39, and 81% Sn after quenching from 750 to 900°C . (1382 to 1652°F .) It possessed a Ni-As structure and corresponded therefore to the formula FeSn , although it is not necessary that this composition fall in the region of homo-

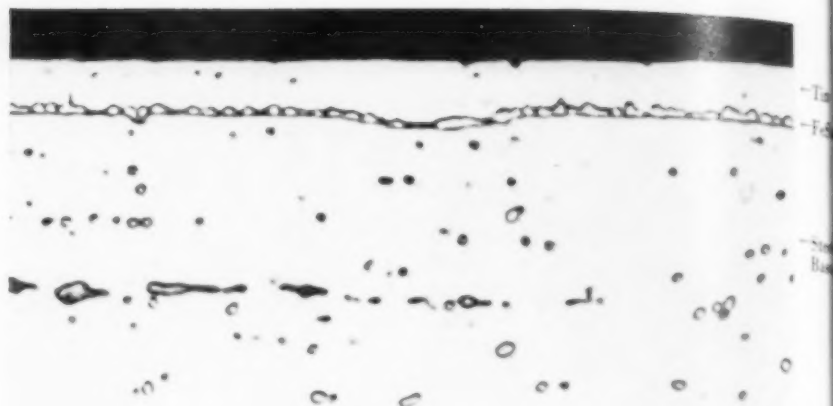


Fig. 5 — Cross Section of Coke Tin Plate. Average weight of coating, 1.46 lb. per base box. Double etched; (a) in nitric and hydrofluoric acids in glycerine, and (b) 5% picral to reveal FeSn_2 alloy layer. Magnified 2500 diameters

geneity. (Comparison with the Ni-As lattice structure in the Fe-Sb system is of interest.)

6. The phase richest in tin possessed a very restricted region of homogeneity. It corresponded to the composition of FeSn_2 and was probably hexagonal, with four FeSn_2 molecules to a unit cell.

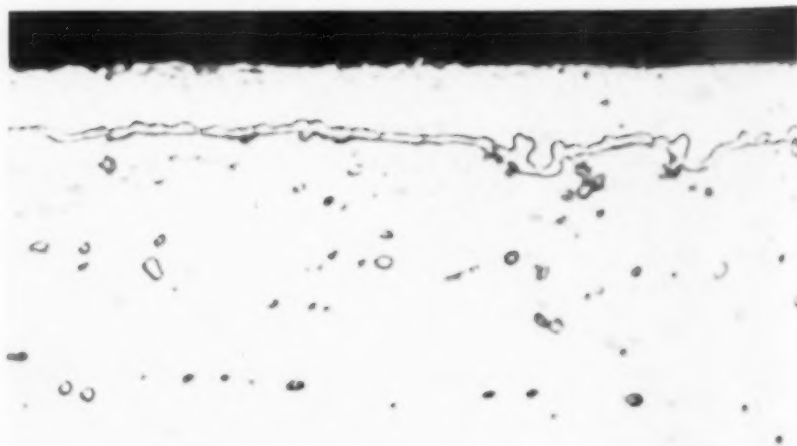
7. Since on all photograms in which the tin phase appeared, diffraction lines occupied positions identical with those of pure tin, it was concluded that iron and the intermetallic phases above mentioned were practically insoluble in tin.

Jones and Hoare³ prepared samples and conducted a microscopic examination in 1934 of iron-tin reaction products in an attempt to reconcile some of the discrepancies between Edwards and Preece's work and Ehret and Westgren's. They

confirmed the existence of three intermediate phases, as outlined by Edwards and Preece, and indicated that the most probable formulas were Fe_3Sn , FeSn and FeSn_2 . However, since all three phases grow readily from melts at the iron-tin interface, they assumed that "they permit of diffusion" and suggested that their representation on the equilibrium diagram as vertical lines may not be warranted. They also questioned the wisdom of assigning molecular formulae to the phases in question. They were also unable to produce the γ phase of Ehret and Westgren at 68.5% Sn and 850°C . (1562°F .)

The writer, in Fig. 1, has attempted, at least partially, to reconcile these variances of opinions, as well as the very recent important work of Ehret and Gurinsky, without making the diagram so indefinite

Fig. 6 — Charcoal Tin Plate; Averaging 3.75 Lb. Tin per Base Box. Double etched; (a) in weak alcoholic hydrofluoric acid, and (b) 5% picral to reveal FeSn_2 alloy



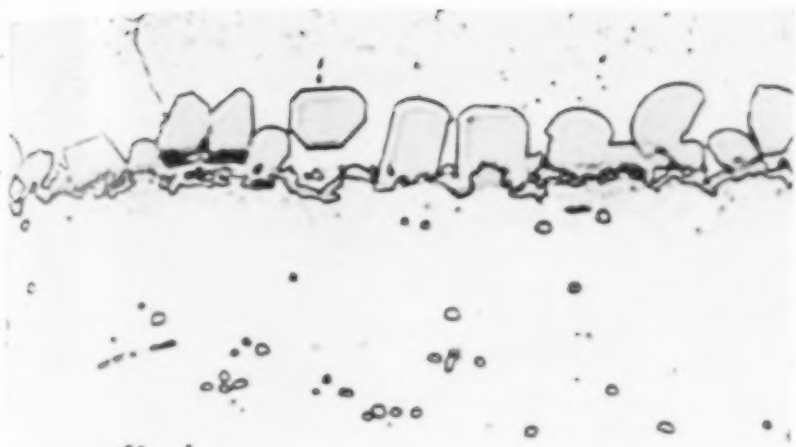


Fig. 7 — Cross Section of Coke Tin Plate Which Had Been Immersed in Molten Tin at 330°C. (625°F.) for 5 Hr. Double etched as in Fig. 6. Magnified 2500 diameters

that it would be difficult to follow by the metallurgist. It seems probable that further careful work is required to clear up the divergence of results and opinions as to the true constitution of this binary alloy system.

Commercial Importance of Iron-Tin Alloys

Perhaps the greatest present importance of the iron-tin alloys relates to the occurrence of an alloy layer on hot-dipped tin plate, or electrolytic tin plate which has been subjected to melting or soldering. The only alloy observed from microscopic examination of cross sections of tin plate or from cross sections taken from tin cans is the compound FeSn_2 . Figure 5 shows a photomicrograph at 2500 diameters of a cross section of coke grade, hot-dipped tin

plate with the constituents designated. Various chemical analyses of this alloy made by stripping off the tin and then dissolving the alloy have yielded results approximating 80.96% Sn, the theoretical composition for this compound.

From the diagram one might wonder if a layer of the compound FeSn were present. However, as far as the writer knows, no indication of such a constituent has been found either on charcoal plate, Fig. 6, or on coke plate which has been heated for a considerable length of time at temperatures slightly below the melting point of tin. Results of chemical and microscopic analyses indicate that only one compound, FeSn_2 , is present in the alloy layer when sheet steel is immersed in molten tin for relatively long periods of time.

Fig. 8 — Cross Section of Electrolytic Tin Plate Subsequently Melted. Average weight of coating, 0.57 lb. per base box. Double etched (a) in nitric acid and hydrofluoric acids in amyl alcohol, and (b) 5% picral to reveal FeSn_2 alloy. Magnified 2500 diameters

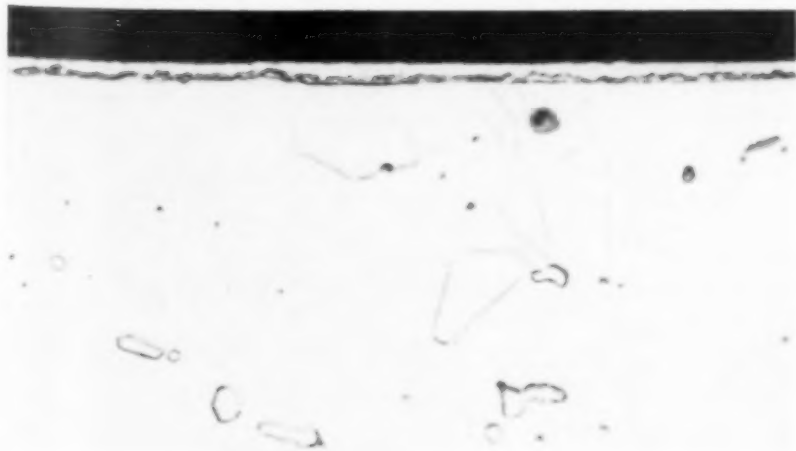


Figure 7 represents a cross section of coke tin plate which had been immersed in molten tin for 5 hr. at 330° C. (625° F.), and shows clearly developed FeSn_2 crystals, some of which drop off and form dross in the tin pot. Except for thickness, the iron-tin alloy layer on melted electrolytic tin plate does not greatly differ in appearance from that of coke grade hot-dipped plate (compare Fig. 5 and 8). Since comparatively low temperatures are used in hot-tinning or melting of electro-tinned coatings—246° to 343° C. (475° to 650° F.)—it is probable, as concluded by Hoare⁹, that "the conception of a secondary compound containing a greater percentage of iron than FeSn_2 lying immediately adjacent to the steel base is not admissible in the case of any hot-dipped tin coatings prepared below 496° C. (925° F.)."

A knowledge of the constitutional diagram may be of some value in the treatment of tin drosses formed in tin pots and which are treated to reclaim tin. Difficulties in dross treatments may be associated with the formation of some of the compounds or constituents shown in Fig. 1, although this problem is made more complex by the possible presence of zinc from the zinc chloride flux.

With the present scrap shortage, steel makers will receive much tin plate scrap for remelting. In the process of detinning such scrap, it is difficult to remove the last traces of the iron-tin alloy FeSn_2 , and thus contamination of the steel with tin may result. The tin present in double-seamed ends and the soldered joint of the body seam of the tin can may also be difficult to remove, and thus more tin is added to the steel melt. Since, as indicated in Fig. 1, tin is soluble in iron to the extent of 9 or 10%, its presence in small amounts may not be detected by the microscope; however, it may be determined by chemical or spectroscopic methods. Rarely is sufficient tin plate scrap used in the charge to yield steel with as much as 0.50% Sn in the ingot, even assuming 100% recovery. The amount of tin permissible in steel without harm will depend on studies as to its effect on forging, hot or cold rolling, heat treatment, final fabrication of the finished steel product, and ultimate performance in service.

Appendix

Shortly after preparation of this manuscript, a paper entitled "The Thermal Diagram of the System Iron-Tin" was presented by W. F. Ehret and D. H. Gurinsky of New York University, September, 1942, before the Buffalo meeting of the American Chemical Society. This paper has not been published, as yet, except in a very brief abstract form²² with no figures, but the present writer was furnished with an abstract of the thesis. These authors chiefly used the technique of heat treating, quenching, and X-ray analysis. The investigation was undertaken to clarify the structure of the Fe-Sn diagram as it concerns equilibria existing above 500° C. (932° F.) and in the range of 10 to 100% Sn. They were particularly interested in studying further the differences in con-

For FeSn, $a_0 = 5.288 \text{ \AA}$; $c_0 = 4.442 \text{ \AA}$; $c_0/a_0 = 0.840$

For γ (Ni-As structure), $a_0 = 4.228 \text{ \AA}$; $c_0 = 5.206 \text{ \AA}$; $c_0/a_0 = 1.231$

For FeSn₂, identical with those reported by Ehret and Westgren.

The differences and additions to results obtained from Ehret-Westgren's X-ray work are as follows:

1. The Fe₃Sn decomposition is lower than that of the γ phase.
2. The γ phase decomposition temperature is probably below 950° C. (1472° F.), the temperature suggested by Ehret and Westgren.
3. The Fe₃Sn₂ phase is now given stability limits and is considered as one phase with complex structure.
4. A discontinuity is thought to exist between γ and FeSn phases.
5. The homogeneity range of the γ phase has been narrowed from that formerly reported.
6. Comparison of the equilibrium diagram (Fig. 9) with those of Co-Sn

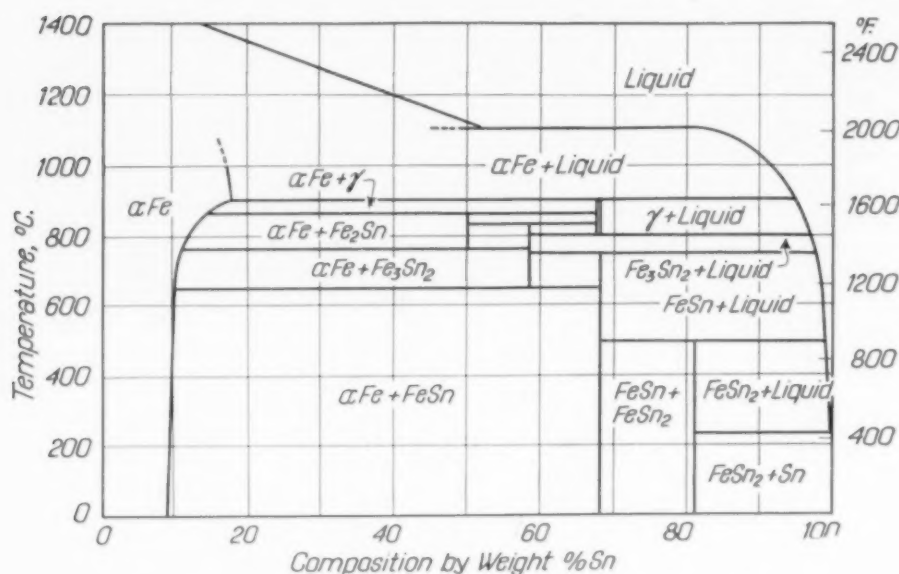


Fig. 9 — 1942 Diagram of Ehret and Gurinsky. (The γ symbol denotes the same constituent as the γ in Fig. 4)

clusions between Jones and Hoare² and Ehret and Westgren³.

Since changes have been made in the diagram as published by Ehret and Westgren (Fig. 4), the new diagram of Ehret and Gurinsky is shown in Fig. 9. They conclude that all phases in the system, other than iron and tin, belong to the hexagonal system and report the following lattice constants:

For FeSn, $a_0 = 5.449 \text{ \AA}$; $c_0 = 4.347 \text{ \AA}$; $c_0/a_0 = 0.798$

For FeSn₂, $a_0 = 21.32 \text{ \AA}$; $c_0 = 4.381 \text{ \AA}$; $c_0/a_0 = 0.205$

and Ni-Sn shows these similarities:

- (a) All three systems possess one phase having the NiAs structure
- (b) The structures of CoSn and FeSn appear to be identical
- (c) Complex structures appear in each system when the atomic ratio is 3:2.

A comparison of Fig. 9 with the diagram reproduced in Fig. 1 shows the following differences:

1. The existence of two phases, γ and FeSn₂, is indicated, which phases are absent in Fig. 1.
2. The presence of Fe₃Sn₂ is indi-

cated below 760° C. (1400° F.), thus decreasing considerably the extent of area KJNPQR in Fig. 1.

Acknowledgments—The author wishes to express appreciation to D. H. Rowland and D. F. Armiento for the photomicrographs and to others in the Pittsburgh research laboratory of Carnegie-Illinois Steel Corp. for aid in preparation of diagrams and for advice and helpful criticism; also to Gerhard Derge of Metals Research Laboratory, Carnegie Institute of Technology, for a critical review.

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Be sure to segregate your alloy scrap



Careful segregation and identification of alloy iron and steel scrap should be standard procedure in every plant collection program.

1. It helps conserve essential, scarce alloying elements.
2. It helps eliminate wasted time, material and effort in the steel mills.

Alloying elements such as cobalt, molybdenum, nickel and tungsten are readily recoverable from scrap. If their presence in a lot is known, the scrap can be used in making up a charge of alloy steel of

the same or similar analysis. The amount of alloying elements that must be taken from stock is reduced.

But, if, through lack of segregation, alloy scrap gets into a charge where no alloys are wanted, such as a plain carbon steel, the alloying elements are utterly wasted. It is also possible that the heat itself will be lost because of failure to meet specifications.

The difficulties of scrap segregation increase with every handling. The source is the best point for segregation. Comparatively little time and trouble taken there will save a great deal of trouble and wasted time at the mill.

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Personals

Earl M. Johnson ☉, formerly employed at the Springfield Armory, is now located at Boston Navy Yard.

Kenneth L. Hulsing ☉ is now in the diesel engine development division of General Motors' Detroit Diesel Engine Division.

Paul A. Jennings ☉, formerly employed at the Ellwood City Works of National Tube Co., is now assistant research metallurgist, Rustless Iron & Steel Corp., Baltimore.

J. E. D. McCarty ☉, formerly with Firestone Rubber & Metal Products Co., Wyandotte, Mich., is now chief research engineer, Simmonds-Benton Mfg. Division, Vergennes, Vt.

Honored at the Society's annual dinner in Cleveland, Oct. 15: Benjamin F. Shepherd, past president ☉, chief metallurgist, Ingersoll-Rand, Inc., awarded the Sauveur Achievement Medal; A. W. Schlegel ☉, metallurgical department, Carpenter Steel Co., the Henry Marion Howe Medal; and John C. Garand ☉, Ordnance engineer, Springfield Armory, a special plaque and certificate honoring his invention of the rifle.

E. R. Mertz ☉ has resigned from the faculty of Stanford University to take a position as metallurgist and chief inspector for United States Spring & Bumper Co., Los Angeles.

R. S. Komarnitsky ☉, formerly with the Breeze Corp. of Newark, N. J., is now chief metallurgical engineer, Standard Steel Spring Co., Detroit.

Columbus Floyd ☉, formerly on the staff of the College of Engineering of the University of Detroit, has accepted a position on the metallurgical staff of the Chrysler Corp.

Lieut. M. C. Gelman ☉, previously stationed in New York City, has been transferred to Federal Tin Co., Baltimore, representing Chemical Warfare Service.

Lieut. N. Levinsohn ☉, formerly metallurgist for the Minneapolis-Moline Power Implement Co., is now with the U. S. Army at Camp Hoan, Calif.

E. W. Husemann ☉, formerly metallurgist at Republic Steel Corp., Chicago, is now metallurgist for Copperweld Steel Co., Warren, Ohio.

Lieut. P. W. Bakarian ☉, formerly with Dow Chemical Co., is now with the Experimental Engineering Section, Materials Division, Wright Field, Dayton, Ohio.

Transferred: George H. Kaiser ☉, from the Cleveland office of Columbia Tool Steel Co. to the Chicago branch as manager of sales in the Chicago district.

National Emergency Alternate Steels

DESIGNATION	CHEMICAL COMPOSITION (b)				
	C	Mn	Mo	Ni	Cr
NE8024	0.22-0.28	1.00-1.30	0.10-0.20	....	....
NE8124	0.22-0.28	1.30-1.60	0.25-0.35	....	....
NE8233	0.30-0.36	1.30-1.60	0.10-0.20	....	....
NE8245	0.42-0.49	1.30-1.60	0.10-0.20	....	....
NE8339	0.35-0.42	1.30-1.60	0.20-0.30	....	....
NE8442	0.38-0.45	1.30-1.60	....	....	....
NE8447	0.43-0.50	1.30-1.60
NE8547	0.43-0.50	1.30-1.60
NE8620	0.18-0.25	1.30-1.60
NE8630	0.27-0.34	1.30-1.60

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and our research facilities are at your disposal to supply "know how" information on any problem involving the use of the oxyacetylene flame and the electric arc.



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Personals

E. B. Pool ☼ is now with the Dodge Chicago Aircraft Engine Division as supervisor of physical testing.

Promoted by Carnegie-Illinois Steel Corp.: Rodney Dean, Jr. ☼, from observer to metallurgist in the Duquesne Works.

Roger Stuart Brown ☼ now represents the Ajax Electric Co. in the New York Metropolitan area, including northern New Jersey and eastern New York State.

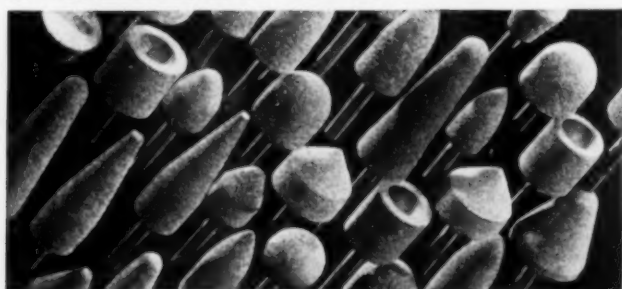
E. H. Dix, Jr. ☼, chief metallurgist, and R. L. Templin ☼, chief engineer of tests, have been named assistant directors of the Aluminum Research Laboratories, New Kensington, Pa.

W. E. Renwick ☼ is now industrial specialist, Graphite Section of Mica-Graphite Branch, Office of Operations, War Production Board, Washington, D.C.

Lieut. E. C. Jasper ☼ has been called to active duty with the Ordnance Department, from his position as chief metallurgist at Stewart Warner Corp., Chicago.

ASMembers who received awards for papers submitted to the recent competition of the James F. Lincoln Arc Welding Foundation: H. Thomasson, welding engineer, Canadian Westinghouse Co., Ltd.; Vladimir H. Pavlecka, chief of research, Northrop Aircraft, Inc.; A. M. Unger, plant engineer, Pullman-Standard Car Mfg. Co.; John H. Hruska, chief inspector, Electromotive Division, General Motors Corp.; Walter J. Brooking, director of testing and research, R. G. LeTourneau, Inc.; James W. Fitch, automotive engineer, Kenworth Motor Truck Corp.; Carlton G. Lutts, materials engineer, Boston Navy Yard, and Paul D. Ffield, materials engineer, Bethlehem Steel Co.; Edgar Brooker, ordnance engineer, Tank and Combat Vehicle Division, Industrial Service, Ordnance Department, U. S. Army; Herman C. Frentzel, chief engineer of tank design, the Heil Co.; J. Schuyten, metallurgist, Shell Chemical Co.; Ralph C. Day, superintendent, tank and trailer shops, Wentworth and Irwin, Inc.; W. H. Rice, assistant professor in welding, Oklahoma Agricultural and Mechanical College; Walter E. Klauberg, design engineer, Wyatt Metal and Boiler Works; Harold F. Wahl, engineer, Willamette Hyster Co.; Edwin Jones Freeman, head of Industrial Engineering Department, Clemson College; Frank K. Zaniker, welding supervisor, Crown Willamette Paper Co.; H. W. Rushmer, research worker, Jeffrey Mfg. Co.; and C. F. Underwood, metallurgical engineer, Jones & Laughlin Steel Corp.

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Contributors to This Issue

IN HIS 20 years with the Stewart Industrial Furnace Division of Chicago Flexible Shaft Co., **John Wallerius** has planned almost every type of forging and heat treating furnace being used today, including many of his own design. He came to Chicago from Sweden and worked up through the ranks of his department to his present position of chief designing engineer. He is a graduate of Bergsskolan, the famous technical school specializing in metallurgy and mining at Filipstad, Sweden, and his first job before coming to America was in the engineering department of Arvika-Verken, the "International Harvester Co." of central Sweden.

Don Gardner, co-author with Mr. Wallerius of the article on shell treating furnaces, is a chemical engineering graduate, Ohio State University, 1933, and has been chemical engineer and metallurgist for Chicago Flexible Shaft Co. for the past five years. His earlier experience was in the metallurgical and chemical laboratory of a large Ohio manufacturing plant doing precision heat treating of chromium, molybdenum and vanadium steels. In his services with the Stewart Industrial Furnace Division, Mr. Gardner has compiled the useful wall charts and vest pocket data books circulated by Chicago Flexible Shaft Co.

Although **James K. Stanley's** main occupation in the Westinghouse Research Laboratories is the investigation of magnetic materials for transformers and electrical machinery, he has also concerned himself with heat treating processes and has some worthwhile ideas on the fundamentals of carburizing for *Metal Progress* readers

(page 849). Mr. Stanley is a metallurgical graduate of Case School of Applied Science (1934), and from then until 1937 did research and development work on aluminum alloys for National Smelting Co. in Cleveland. He joined the Westinghouse Co. in 1937 as research engineer.

For four of the five years since **Raymond J. Hafsten's** graduation from University of Alabama in 1937 (B.S. in Metallurgical Engineering), he was with Carnegie-Illinois Steel Corp. and the U. S. Steel Research Laboratories in Kearny, N. J. In 1941-42 he was chief metallurgist for Firestone Steel Products' Fall River, Mass., plant, where 50-caliber machine gun links were being manufactured. He is now research metallurgist for Armour Research Foundation, Chicago.

O. E. Romig's education took him from Pacific University (A.B. in Chemistry, 1920) to Oregon State College (B.S. in Chemical Engineering, 1922) to Harvard University (A.M. 1924, major in metallurgy under Professor Sauveur). Starting out in the field of metallography, he worked under Dr. Hoyt at the G.E. research laboratory in Schenectady, and then for the American Sheet & Tin Plate Co. In 1926 he was made chief metallurgist of the Vandergrift Works of American Sheet & Tin Plate, in 1930 chief metallurgist of the Gary sheet mill, and in 1936 manager of the electrical sheet division. Since 1937 Mr. Romig has been assistant research engineer for Carnegie-Illinois Steel Corp.'s research laboratory at Schenley Park in Pittsburgh. He specializes in the metallurgy of flat-rolled, coated and uncoated steel products.



JOHN WALLERIUS



R. J. HAFSTEN



O. E. ROMIG



JAMES K. STANLEY



DON GARDNER

Personals

Marvin J. Udy ☉, vice-president in charge of research and technology, Chromium Mining and Smelting Corp., Ltd., has been elected to the Board.

Promoted: H. M. Oshry, Ordnance Department, from first lieutenant to captain.

Glenn Sowders ☉, formerly with Henry L. Hanson, Inc., Worcester, Mass., is now in charge of the high speed and tool work at the Massachusetts Steel Treating Corp., Worcester.

Transferred by Chrysler Corp.: Edgar W. Jones ☉, from engineering division at Highland Park, Mich. to Evansville Ordnance Arsenal, Evansville, Ind., in charge of laboratories.

H. W. Graham ☉, director of metallurgy and research, Jones & Laughlin Steel Corp., Pittsburgh, has been appointed member of a committee of engineers and scientists to determine the manner in which the projected Office of Technical Development should be set up within the War Production Board.

Harry Walther ☉, assistant melting superintendent of the Timken Roller Bearing Co., has been elected president of the Electric Metal Makers Guild.

Perry R. Cassidy ☉, former executive assistant, the Babcock & Wilcox Co., is now lieutenant colonel in the Engineers Corps, U. S. Army.

A. E. Flanigan ☉ has been relieved of teaching duties at Illinois Institute of Technology to accept the position of research associate on a National Research Council metallurgy project, and is located at University of California.

Transferred: Floyd L. Wile ☉, inspector of ordnance material for the Cincinnati Ordnance District, from Guide Lamp Division, General Motors, Anderson, Ind. to Bridgeport Brass Ordnance Plant, Indianapolis.

C. C. Snyder ☉, formerly sales metallurgist, Republic Steel Corp., Massillon, Ohio, is now chief of the Ferrous Metals Section, Conservation Division, War Production Board.

G. A. Sellers ☉ has resigned as professor of metallurgy and metallography, School of Engineering, Kansas State College, Manhattan, Kans., to accept a position as chief metallurgist of the Boeing Aircraft Co., Wichita Division, Wichita, Kans.

Wesley M. McGhee ☉, formerly chemical engineer for Automatic Electric Co., Chicago, is now chemical engineer for E. I. du Pont de Nemours & Co., Memphis, Tenn.



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November, 1942; Page 911

Surface Preparation for Spot Welding Aluminum*

■ AT LEAST 75% of the troubles experienced with surface spitting, weld spitting, irregularity in weld shape and electrode pick-up can be attributed to improper surface preparation. The purpose of surface

preparation of aluminum and aluminum alloys is to eliminate variations in the heat of welding, due to variations in the contact surface resistance of unprepared aluminum sheets, and to reduce to a minimum the heating

between the aluminum sheet and the welding electrodes supplying current to the weld.

Surface resistance is caused by the presence of foreign substances, either deposited on the sheet in the course of handling or formed chemically by the action of atmosphere or other agents. The mechanical and chemical films are in no way similar, and different methods must be used for their removal.

Since the fundamental principle of spot welding is creation of fusion between the inner surfaces of the parts joined but not on their outside surfaces, the heat produced between electrode and sheet can be only harmful, particularly since the aluminum sheet and the copper electrode alloy readily one with another. It is therefore imperative to remove both dirt and oxide film to insure welds with good surface appearance, to minimize electrode pick-up, and thus increase electrode life.

The need of removing the film *between* the surfaces being welded is equally great. Any mechanically deposited oil or dirt cannot be uniform, and therefore will introduce variable contact resistance and the amount of welding heat generated, which in turn will vary the extent of fusion. The chemical film of aluminum oxide present on all aluminum is also non-uniform in character, and frequently of such magnitude that break-through requires an appreciable potential, with the result that when it occurs the current is sharply localized which in turn

*Extracts from "Tentative Standards and Recommended Practices and Procedures for Spot Welding of Aluminum Alloys", issued as emergency standard by American Welding Society, August 1942.



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results in excessive local heating, expulsion of weld metal from the weld, weld cavities, and irregularity in the shape of the welds.

There are a number of means of removing dirt or oil from the surface. Any grease-dissolving operation combined with mechanical agitation such as spraying or wiping action is satisfactory. Vapor degreasers and chemical baths are best, though with proper supervision and technique, hand wiping with acetone or alcohol, though less dependable, can also serve.

Oxide can be scraped off by the abrasive action of steel wool, wire brush or powder, sufficiently severe to cut through the oxide film yet gentle enough to prevent a scratched surface, or to guard against appreciable removal of the aluminum cladding. For this reason the bristles of wire brushes must not be over 0.004 in. diameter and the abrasive not over No. 240 aloxite cloth. Mechanical preparation has the advantages of leaving no second film behind, of permitting local application where needed, and of using cheap equipment. Its disadvantages are high labor cost and high personal factor of the workman. It is therefore applicable best in small shops.

Chemical Agents — There are a number of chemical agents which will attack the aluminum oxide film; unfortunately, most of them will attack the metal itself though a few will not attack some specific aluminum alloys such as, for instance, 52S.

In chemical cleaning, therefore, time of exposure is of great importance. Hydrofluoric acid, 3% by volume, is probably the most powerful agent for attacking aluminum oxide film. Its action on the material itself is just as violent and therefore the operation, although very fast, is very critical and must be done with extreme care.

Sodium hydroxide (caustic soda) is another powerful reagent. However, it attacks the

material itself even more rapidly than the oxide film, forming a deposit of high resistance so that its use also is dangerous and very critical insofar as time is concerned. Although it was one of the first agents to be tried, its use is not recommended.

Mild acids with sulphur base appear to be in some ways superior to other chemicals since their action is slower and the time much less critical. Prepa-

rations of the type of Oakite 84-A Solution appear to be the best at this time. They attack the oxide film comparatively rapidly and their action on the metal is considerably delayed.

Advantages of the chemical dip include uniform results, reproducibility, low labor cost. Disadvantages are the need for accurate control, the hazards of corrosive chemicals, and costly equipment. (Continued on p.929)

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Die sets often operate at extremely high speed — open, close; open, close — thousands of cycles hourly — millions yearly — yet the guide pin bushings that control accuracy in this process must never vary — must resist wear and maintain alignment. Here Ampco Metal again proves its merit.

Perhaps Ampco Metal costs a trifle more, but the increased life of the parts made from the alloy proves its economy. It outwears other metals — gives a fuller measure of value. The ultimate cost is always low.


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THE METAL WITHOUT AN EQUAL

Tin From Cans

(Continued from page 876)

The second step in the program is substitution of electrolytic and bonderized steel *ends* for cans wherever the nature of the pack permits. This will save 3500 tons of tin in 1943.

The third step is substitution of electrolytic tin plate *bodies* wherever practical. This will save an additional 4300 tons.

The fourth step is use of electrolytic tin plate and bonderized steel for both bodies and ends wherever possible, for an additional saving of 3300 tons. The total estimated to be saved by this program per year by 1943 is thus about 10,000 tons.

An interesting problem devel-

ops in connection with the fourth step, which may alter the program somewhat. The primary objective is to save tin. Tin is needed for coating the steel, and for solder to seal the joints. A balance of these two needs must be achieved to get maximum savings. In the all-bonderized can, a tin-lead solder must be used, whereas in a combination electrolytic-plate-bonderized can, silver-lead solder can be used. The saving of tin in solder in the latter case may easily amount to more than that from the use of electrolytic plate.

Production of electrolytic tin plate involves deep-seated changes in tin plate production, and it cannot be accomplished over night. Entire new plants, costing millions of dollars, possibly a total of \$75,000,000, must be built. The plating tanks are as deep as a two story house. Such construction is at the expense of critical materials of the most urgent nature required for other vital war construction; therefore, unlimited new electrolytic plant cannot be built.

The present construction program, now well under way, will provide 27 tin lines and 18 bonderizing plants, enough capacity to permit the savings outlined above by 1943. Some are in the same plants containing hot dip units. Unfortunately, conversion of tin dip plants to electrolysis is not possible.

Another obstacle, and one which is not yet solved completely, is the need to heat treat the electrolytic plate after plating to develop a metallurgical bond — really an alloying of the tin and steel. This is necessary to permit efficient soldering of the cans, and to provide a surface which will take enamels satisfactorily. Experiments are now being conducted on this phase of the problems.

The broad tin conservation program includes substitution of other materials for tin wherever

(Continued on page 928)

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to
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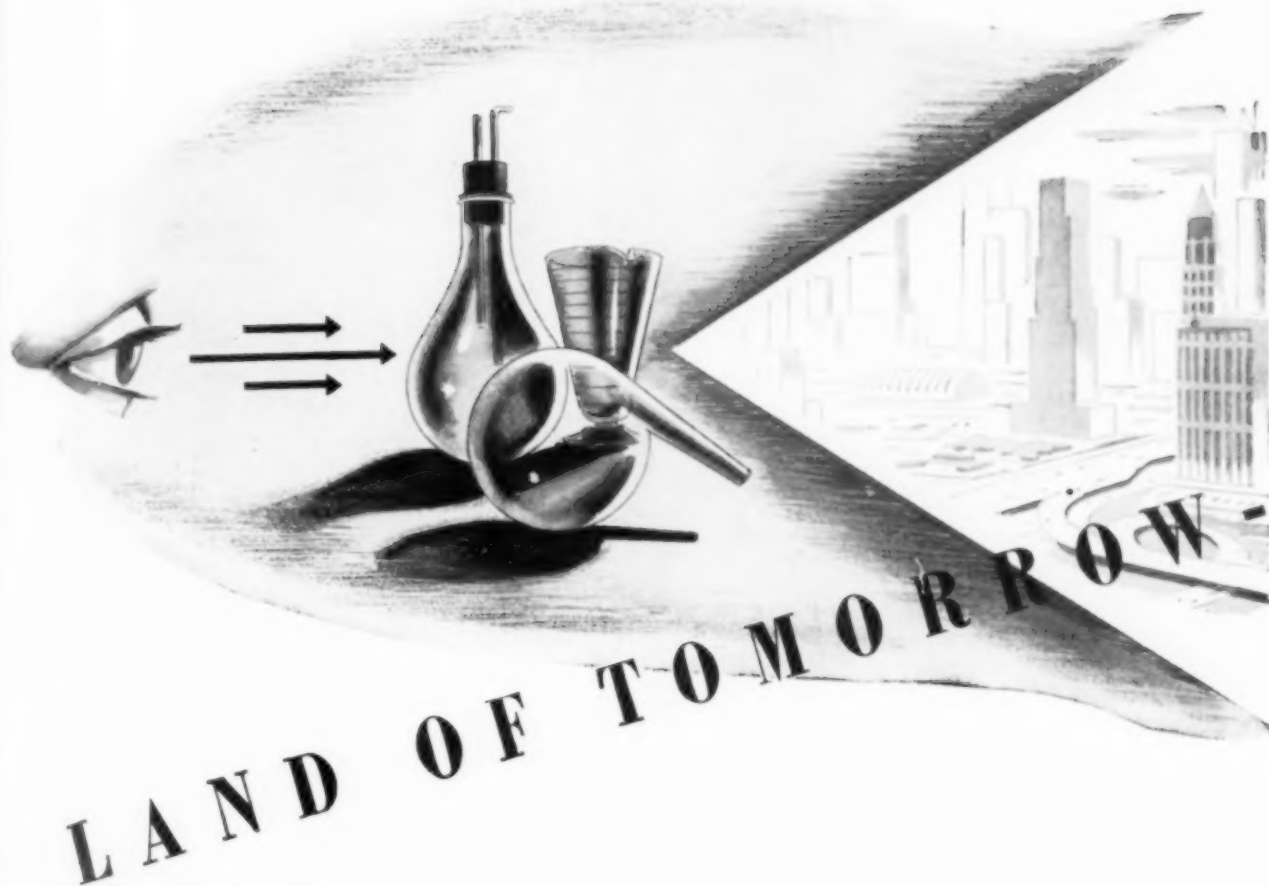
When General Doolittle and his squadrons made their surprise raid over Tokio, they carried a message of things to come—the only type message Japs can understand! Naturally we are proud that the equipment of these planes contained wire made by Wilbur B. Driver Co. The entire facilities of our plant are devoted to producing, as never before, special alloys* (including beryllium-copper) for all war purposes. Consult us for your requirements.

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(Carborundum is a registered trade-mark of and indicates manufacture by The Carborundum Company.)

November, 1942; Page 915

Copper Clad

(Continued from page 866)

Co. at Carteret, N. J., and Copperweld Steel Co. at Glassport, Pa.

Calumet & Hecla have operated for many years a cupric ammonium carbonate leaching plant in the treatment of copper

ores, especially tailings containing native copper dredged from Lake Linden. They also have, for the past couple of years, commercially treated copper-clad steel scrap. The Lake Linden plant now has capacity to treat 2500 tons per month of gilded steel, and the company is ready to accept this amount of material immediately. Additional leaching capacity for 7500 tons monthly exists, but oxidizing

equipment for the treatment of the additional material would have to be built. Furthermore, existing smelter capacity can handle the entire tonnage of copper oxide which should result from the processing of 20,000 tons of gilded steel per month. However, no recovery of zinc fume would be made under the present operating conditions at the plant, but a recovery plant could be installed.

[Briefly the process, as described by Hayward in "An Outline of Metallurgical Practice", is: Dredged tailings are leached with cupric ammonium carbonate and ammonium carbonate solutions containing about 0.35% Cu, 1% NH_3 and 0.8% CO_2 until the liquor contains about 0.85% Cu, and finally washed with steam to drive off remaining ammonia (which is recovered). The enriched solution is evaporated and boiled to decompose the ammonia compounds and some of the carbonates, the NH_3 and CO_2 being recovered in absorption towers. During this operation the copper precipitates as CuO . When treating gilding metal, zinc is also recovered as oxide; in smelting the mixed oxides to metal the zinc would go into the slag and fume, and most of it can be recovered from these byproducts by methods now in large-scale operation in western smelters.]

Copperweld Steel Co. has, for a number of years, been interested in and experimented with the recovery of the copper and iron from its own plant scrap, and now has a pilot unit under construction for treating some of it. The American Metal Co. has operated an ammonia leaching plant for a number of years in recovering zinc from the flue dust at Carteret. These three companies are all qualified to construct and operate leaching plants for the treatment of gilded-steel scrap. Aside from the matter of transportation,

(Continued on page 918)

Speaking of versatility—here's one day's production in a Detroit Electric Furnace



Coal pulverizer hammers—3.75% total carbon.
A Nickel-molybdenum heat—2.65% total carbon.
Heat resistant stoker parts (molybdenum-chrome iron), 2.90% total carbon.
Housings and small soft castings of plain iron—3.50% total carbon.
Marine cylinders of nickel-chrome, molybdenum iron—3.10% total carbon.
Cover plates cast of a special white iron—2.15% carbon—subsequently heat treated.
Nickel-chrome cylinder liners 3.25% total carbon; and large marine piston rings poured from the same iron.

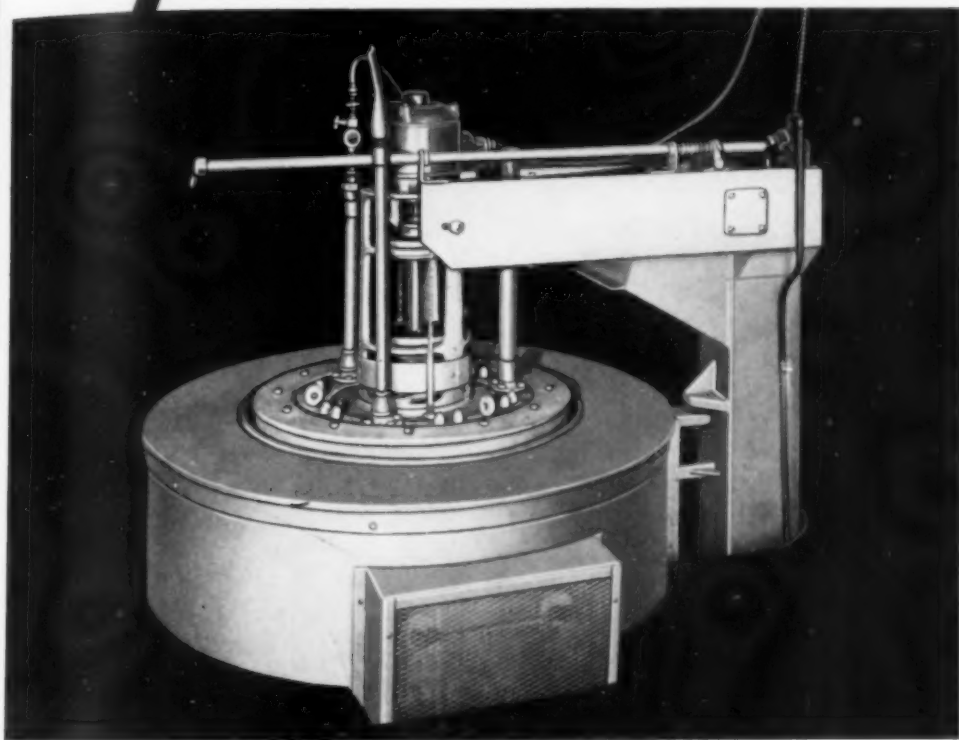
You will note in this typical example of one day's production that castings ranged in carbon content from 2% to 3.75%. Plain and alloyed irons—both white and gray irons—were run throughout the day in rapid sequence as desired.

In addition to versatility, the Rocking Electric Furnace is fast and efficient. Easy to use, it results in a higher percentage of good product, lower metal losses, less labor, less plant space and the frequent use of salvage materials. Write for further facts.



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MILWAUKEE, WISCONSIN

Copper Clad

(Starts on page 866)

Calumet & Hecla is in the best position to carry on the work by constructing additions to the present plant. From the standpoint of transportation, it appears that the Cleveland or

Pittsburgh area is the best location if a single central unit is contemplated. For proper recovery, flat pieces should be cut in 6-in. squares and crimped to prevent nesting. In no case should the gilded steel be baled.

Estimates have been prepared showing that scrap can be reclaimed for about \$5.00 per ton (if 3-year amortization of plant is permitted this would be \$9.00 per ton). The last figure would

represent recovery of copper, as oxide, for 2.5¢ per lb. There will be an additional charge against it of from 2 to 3¢ per lb. in the conversion of the oxide to electrolytic copper, representing the treatment charge by existing smelters and refiners. This charge could be cut approximately in half if a fire-refined copper bullion were produced, and this should be a satisfactory product but probably cannot be done in existing smelters other than the Hubbell plant of the Calumet & Hecla Consolidated Copper Co. in Michigan. This company, however, can and would process the total contemplated tonnage of copper oxide if it were desired that they do so. Shipment of oxide, however, is a serious problem.

The estimated recovery of steel is 100%; of copper 96.5%. The steel left behind in the ammonium leach should be a clean product, and if it were compressed into bundles, it could probably be classified as a No. 2 bundle, taking a price equivalent to No. 1 heavy melting steel.

Other Methods

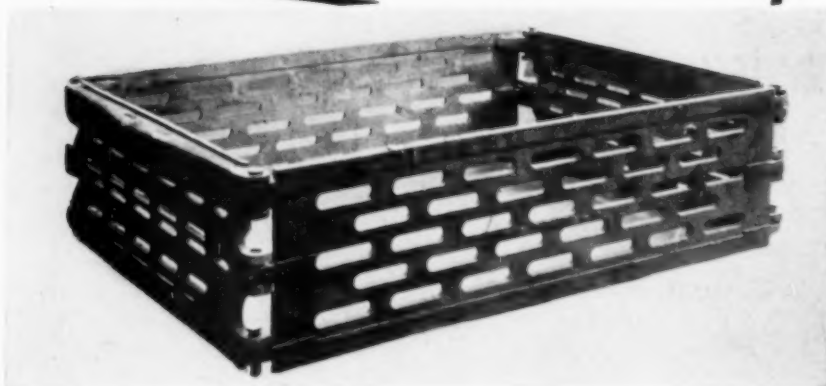
Electrolytic methods have been considered by three firms:

American Metal Co. has experimented with an ammoniacal electrolyte. Copper went into solution readily, but only about 10% deposited on the cathode—probably due to surface oxidation, a trouble for which no ready cure is apparent. Likewise there seems to be no simple and efficient way of handling the scrap as anode material, and excessively large electrolytic tank areas would be required. On the basis of costs, both production and construction, it does not appear likely that this electrolytic process could compete with a leaching method. Copperweld Steel Co.'s experiments verify these conclusions.

Automatic Gasflux Co. of
(Continued on page 920)

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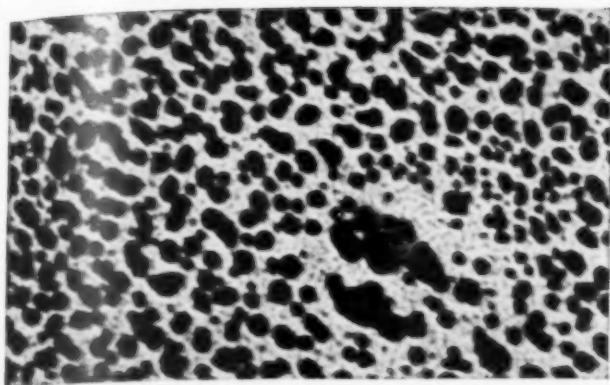
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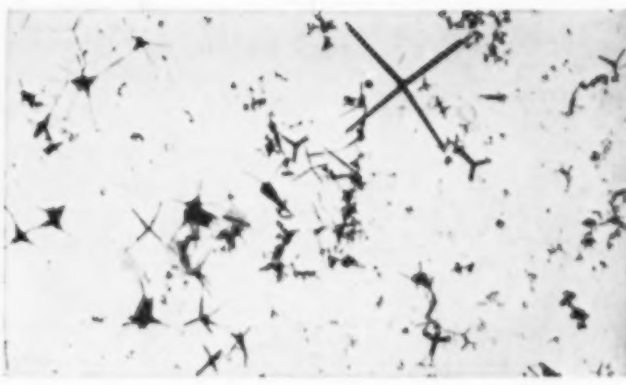
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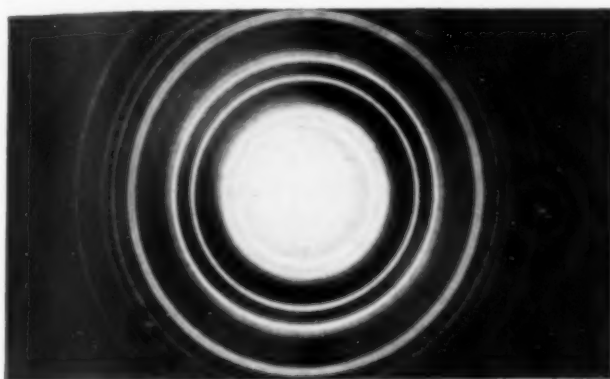
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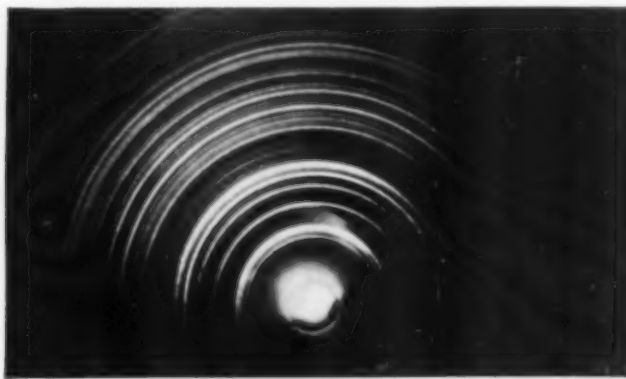
Evaporated silver film, magnification 100,000 x. The RCA Electron Microscope reveals the film is not continuous but consists of extremely fine particles, whose average size is less than one two-hundred-fifty-thousandths of an inch.



Electron micrograph of zinc oxide smoke film formed by burning pure zinc in oxygen. For the first time the very fine parts of zinc crystals can be seen. Below is diffraction pattern of same specimen taken with Electron Microscope diffraction adaptor.



A transmission electron diffraction pattern of the thin silver film shown above. Diffraction patterns indicate the structure and physical arrangement of the atoms in the material.



The reflection method is here used to obtain the diffraction pattern of zinc oxide. When the material is too thick for transmission, the reflection method achieves equally good results.

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RCA ELECTRON MICROSCOPE

RCA MANUFACTURING COMPANY, INC.
CAMDEN, NEW JERSEY

November, 1942; Page 919

Copper Clad

(Starts on page 866)

Cleveland has had in mind the electrolysis of this scrap in a cyanide or sulphate bath. On the basis of a few simple tests, costs are estimated at around 10¢ per lb. of recovered copper.

American Metal Co. has also tried to develop a suitable scaling procedure. The method consisted in heating the gilded scrap to a temperature somewhat below the melting point of the copper-zinc alloy and water-quenching. A recovery of from 50 to 60% of the copper and zinc could be obtained as a mixture of metal and oxide scale. A second scaling treatment following the first resulted in practically

no additional recovery of values. Scaled scrap was then leached.

This work did not live up to its original expectations, and the present unanimous opinion of the experimenters is that this method has no particular merit, either when used by itself or as a part of a leaching process. The main defects are:

1. It will not by itself give a satisfactory recovery of the metals.

2. When used in conjunction with leaching, the heat treatment renders some of the copper so alloyed or combined with the iron that after the leaching the iron still contains 2 or 3% of copper.

3. The copper that remained with the steel required a much longer time for solution in the ammonia solution than did the original material.

Copperweld's laboratories also worked with sulphide scaling, wherein bi-metal is dipped into molten sulphur, and the copper sulphide formed is ground or broken from the iron core. A sulphide layer $\frac{1}{16}$ in. thick is formed in 4 min., which is brittle and easily broken from the iron. However the resulting steel is so high in sulphur that it is almost worthless.

In addition to the above-mentioned procedures, the Copperweld Co. has experimented with ammonium sulphate as a leaching agent. The copper is dissolved from the iron with the ammonium salt, and is precipitated from the leach with sulphuric acid. Copper sulphate is recovered, and the re-formed ammonium sulphate is returned to the leaching circuit. The sulphuric acid which is consumed in the precipitation stage could be recovered if the copper were subsequently deposited by electrolysis. While this process is simple and undoubtedly workable in all its phases, it would require time to develop, and it offers no essential advantages over the ammonium carbonate method.

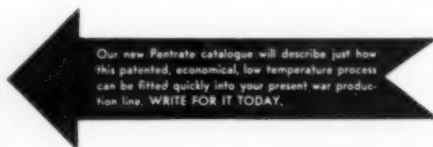


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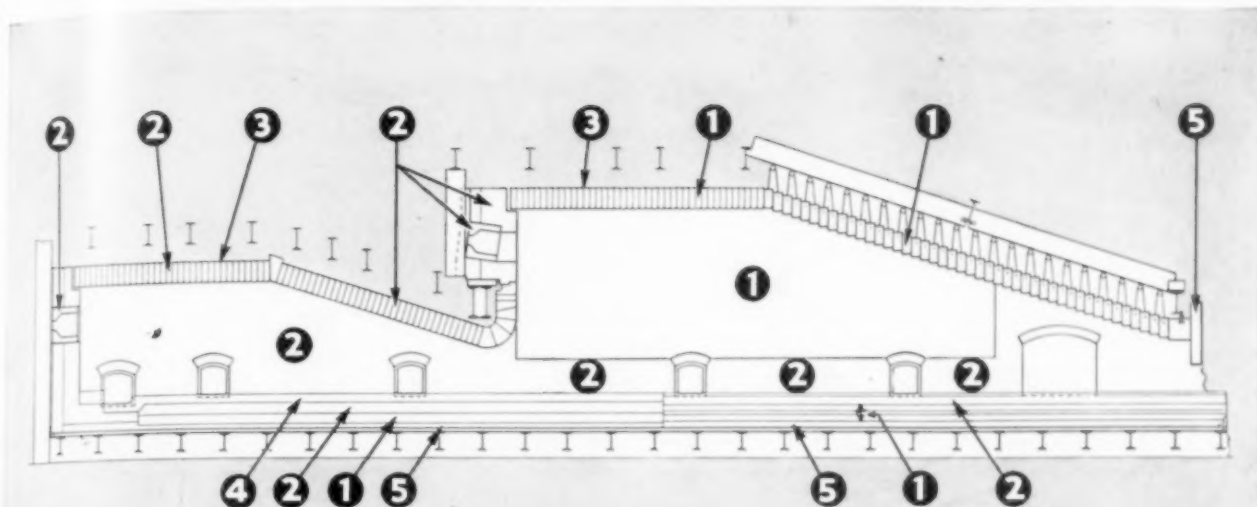
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Cutting of Steel

(Continued from page 889) shells, should be cooled slowly through the critical range after forging to produce a lamellar pearlitic structure with free ferrite, in order to get satisfactory machinability on roughing cuts.

Speeds—High cutting speeds, obtainable with carbide-tipped tools, produce a surface quality often greatly superior to that obtained with high speed steel tools operating at their highest capacity. At sufficiently high speeds the cutting edge of the tool actually does the cutting, whereas at slower speeds the work splits apart ahead of the edge. Favorable results were cited when milling with carbide-tipped cutters at speeds two to three times the lower maximum. Negative rake was given the cutters and exceptionally high quality surfaces resulted.

Coolants—Cutting fluids of the emulsion class are commonly used with carbide tipped tools, and they should be flooded on in large quantities and continuously. The chip often prevents the coolant from reaching the actual cutting edge; excessive temperature changes will then result in cracked tools. Emulsions or coolants serve to break up the chips although many applications of carbide tools are performed better when cutting dry than with inadequate quantities or improper application of the coolant. Sulphurized oils are generally not to be used on carbide tools inasmuch as they act unfavorably on the binder.

Practices at a large manufacturing plant making mechanical bearings were given in detail. Emulsions of one part soluble oil to ten parts water are used as coolants and corrosion preventives on large forgings of alloy steel. On multiple-spindle screw machines a mineral oil containing 6% of lard oil is used; this mixture cooled the tools and lubricated the exposed moving parts of the machine. Emphasis was placed on the cooling properties of the cutting fluid and it was stated that, as an example, the oil on one screw machine rose to 135° F. during the day's run. After installing a cooler to maintain the cutting oil at from 80 to 85° F., the production was increased by 15%. As the sulphur from sulphurized oils is carried by the chips back to the steel making furnaces, sulphurized oils are not too good for subsequent remelting into high quality alloy steel. 



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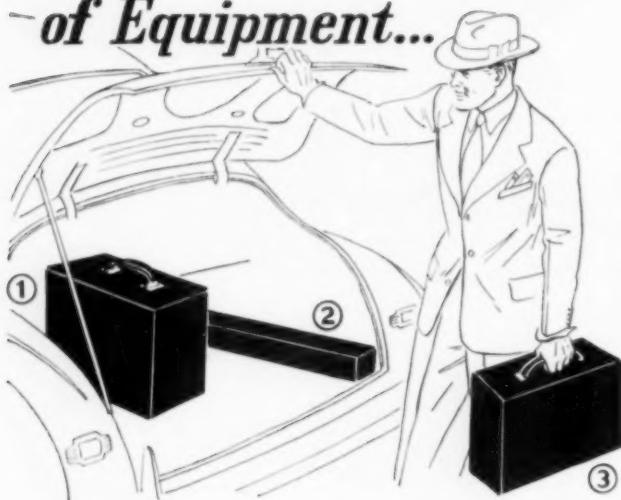
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(Carborundum and Globar are registered trade-marks of and indicate manufacture by The Carborundum Company)

November, 1942; Page 925

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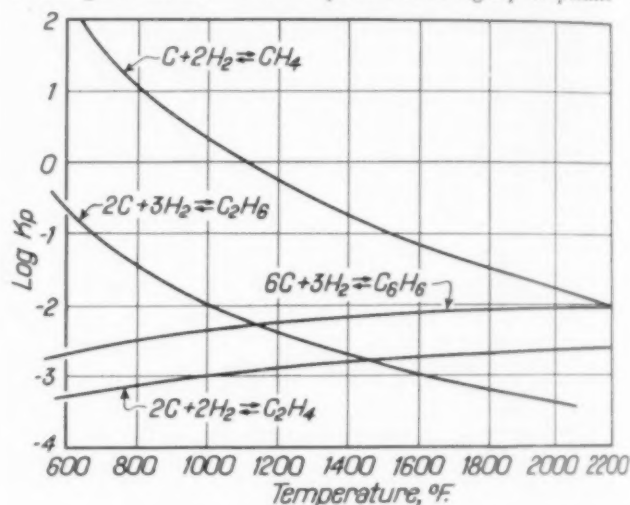


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Soot Deposits*

(THE LEADING ARTICLE in this issue of *Metal Progress* discusses the simplest theoretical process of gas carburizing. In practice there are always hydrocarbons, hydrogen and water vapor present, even when using solid carburizers in boxes. When using gas for the carburizing agent alone, the hydrocarbons may in fact be in excess, and deposit annoying soot. The factors of temperature and composition which cause soot deposits—or, the opposite action—are therefore important to the metallurgist. Consequently the paper by Dr. Rueckel, one part of which is abstracted below, is worthy of attention, since it describes successful methods of handling a mixture of rich coke oven gas and lean flue gas or

Fig. 1 — Variation in Equilibrium Constant ($\log K_p$) for "Carbon Forming" Reactions. Soot is deposited when $\log K_p$ is positive



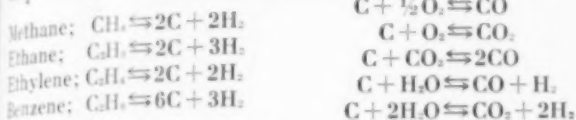
blast furnace gas for firing by-product coke ovens without plugging up the combustion chambers and flues with soot.)

Recirculation of waste (combusted) gas in coke oven flues increases the length of the flame, but the more important advantage is in "autogenic decarbonization". All of the batteries employing the new system have been singularly free from carbon deposits in the gas risers of the underjet ovens, without the addition of any external air for decarbonizing.

Constituents in coke oven gas responsible for carbon formation are ethane, methane, and the illuminants like benzene and ethylene. The chem-

* (Abstracted from "New Principles in Heating Coke Ovens", by W. C. Rueckel; paper read before Eastern States Blast Furnace and Coke Oven Association, Feb. 13, 1942.)

ical reactions involved in both the deposition of carbon and its autogenic consumption are reversible, and definite equilibria are established which are related to the temperature and partial pressures of all constituents involved. The more important reactions follow:

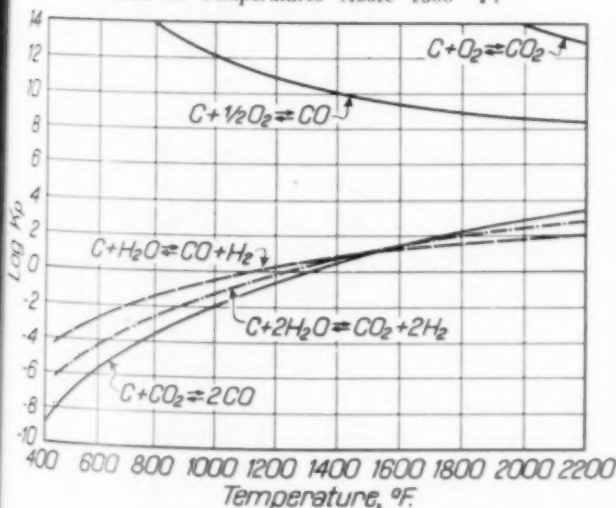


The equilibrium constant (K_p) of the carbon consuming and carbon forming reactions is presented in two graphs. In Fig. 1 it should be borne in mind that values above the zero axis theoretically indicate the reverse reactions in which carbon can be consumed. With the exception of methane, the other constituents benzene, ethylene and ethane deposit carbon when in a temperature range encountered. (While theoretically carbon and hydrogen can form methane at temperatures below 1100° F., this reaction is most unlikely except in the presence of a catalyst. Oxygen is the real carbon consumer.)

Equilibrium data for the so-called carbon consuming reactions are shown in Fig. 2. Since all curves are above the zero axis at temperatures above 1300° F., all the indicated reactions consume carbon at those high temperatures. The reaction of oxygen and carbon to form carbon monoxide and carbon dioxide can also proceed at extremely low temperatures. These reactions are constantly at work during the entire period of the "on gas" cycle both to consume carbon and inhibit its formation when there is oxygen, carbon oxides or water vapor present.

While the foregoing discussion describes the direction in which the various equilibrium reactions progress at certain temperatures, it should be remembered that dilution with waste or inert gas (nitrogen) will decrease the rate at which the less stable hydrocarbons react to form carbon. ☼

Fig. 2 — Carbon Consuming Reactions Are Active at Temperatures Above 1300° F.



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Address _____

Tin From Cans

(Continued from page 914)

possible. Certain large canning plants are expected to install one or more production lines for use of glass containers. This can be done adequately only in the large plants, where one out of perhaps 25 lines will be so converted. Container filling lines are expensive in critical materials, skilled labor and machine facilities, so they cannot be built except where marked tin savings will be accomplished. It is obvious that substitution of glass for tin in such a case would save three times as much tin as would substitution of glass for 0.5-lb. electrolytic tin plate.

The great unknown in the tin conservation program at present is scientific knowledge of what products can be packed successfully in what kinds of containers. It is not known exactly whether electrolytic tin plate or bonderized steel will preserve some foods. The only way to attack this problem is to pack the product in the suggested cans, store it for six months, and see what has happened. This research cannot be hurried, and it is not expected that reasonably full information can be available before the 1943 season.

Advisors to the War Production Board believe that all these factors will come out at about the same time—in time for the 1943 pack of foods. The electrolytic tin plate plants will be completed, and the research on container suitability will be fairly well along, so that the 1943 food pack will take full advantage of the planned savings—10,000 tons of critically needed tin. This yearly saving amounts to over 10% of a peacetime year's total consumption, and in 1943 will run close to 25% of the year's essential demands.

Spot Welding

(Continued from page 913)

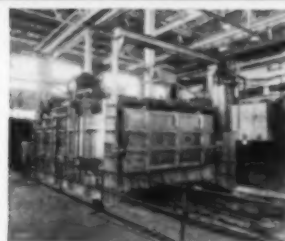
Recommended Practices

For shops working principally with alclad, 2S (commercial aluminum) and the alloys like 3S, 52S and 53S containing practically no copper: Degrease in vapor type degreaser, or by immersing 5 to 10 min. in Oakite Aviation or Oakite 63, 3 to 6 oz. per gal. at 180° F. Give a good cold water rinse immediately, sponge off any residue and rinse again. A surface to support a water film is desired. Later, as convenient, deoxidize the surface in Oakite 86-A, 6 to 12 oz. per gal. at 180° F. Temperature and concentration are critical. Time depends on gage; 24S-T alclad, for example, requires from 2 to 4 min. for 0.016-in. gage, and proportionately up to 3 to 7 min. for 0.084-in. gage. After this dip, immediately give a good cold water rinse, again sponging off any residue, and then without delay dry thoroughly.

Shops working principally with the alloys containing considerable copper (61S, 24S, 17S) require a more drastic operation after degreasing. First the metal should be dipped in Oakite No. 30, 6 oz. per gal. at 190° F. for ½ to 4 min. depending on condition of the surface, then rinsed in cold running water and immediately put into a 10% solution of nitric acid by weight for 1 to 3 min., long enough to remove the black scale. A cold running water rinse, accompanied with sponging, finishes the operation, except for rapid drying.

As soon as the surface is prepared for welding, the chemical action of the atmosphere and the mechanical action of the deposition of dirt begin to undo the work; therefore, in general, the surfaces prepared should be welded within 24 hr.

DEMPOSEY INDUSTRIAL FURNACES



Bomb or shell heat treating furnace.



Continuous belt conveyor type heat treating furnace



Dolly and tray type recirculating furnace.

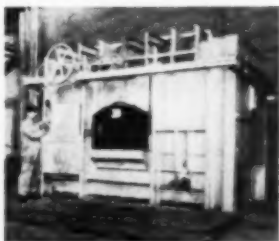
There is a
DEMPOSEY FURNACE
for
every Heat Treating requirement
Recirculating—Continuous Conveyor
Bright Annealing—Clean Hardening
Shell Forging—Shell Heat Treating
Shell Nosing—Billet Heaters
Cartridge Case Annealers
Coil Annealers
Normalizers



Large-capacity air recirculating furnace with chain conveyor.



Continuous normalizing, annealing and heat-treating furnace.



Non-ferrous reverberatory melting furnace... front or top charging



Carburizing, annealing and general heat-treating oven furnaces.



Over- and under-fired car type annealing, stress relieving and normalizing furnace.



Pot furnace for heat treatment in liquid bath.

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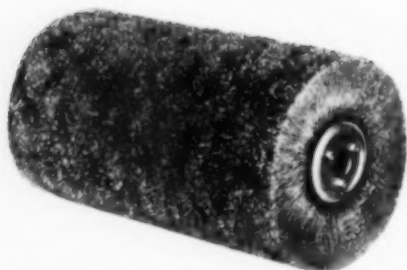
DEMPOSEY INDUSTRIAL FURNACE CORPORATION

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FURNACES—OIL & GAS BURNERS

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CALLITE WIRE "gets around" fast in Samson Rotary Wire Wheel Brushes—around 5,000 feet a minute—in this all-important step in the manufacture of tinplate. Faced with an unusual set of wire requirements—high-speed stamina to clean strip steel—gentleness to preserve the steel's high finish—stout resistance to water rust and corrosion—the Manufacturers Brush Co. naturally decided to call in Callite.

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CALLITE FINE WIRES FOR EVERY NEED

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STAINLESS STEEL	EVERDUR	SILVER
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(levigated alumina) is unequalled in quality and guaranteed to give perfect results. It is the standard polishing powder in modern metallography. RITE-TONERDE is made in 3 grades, #1, #2 and #3, for hard, medium and soft steels, to meet the specific conditions prevalent in metallurgical laboratories.

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GREEN-ROUGE POLISH (levigated Chromic Oxide)

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The RITE-PRODUCTS are independently manufactured in our plant, in Irvington, N. J., by

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RITE-MOLDCOTE, now the best sprayable coating for ingot molds, etc.

These Questions On FORGING METALS

Can it be forged?
What is most suitable steel?
Can non-ferrous serve?
Does it machine readily in the heat-treated condition?
How about the fibre direction?

... and HUNDREDS more
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AMERICAN SOCIETY FOR METALS
7301 Euclid Ave. Cleveland, Ohio

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC.

Required by the Acts of Congress of August 24, 1912, and March 3, 1933, of *Metal Progress*, published monthly at Cleveland, Ohio, for October 1, 1942.

State of Ohio ss.
County of Cuyahoga

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Ray T. Bayless, who, having been duly sworn according to law, deposes and says that he is the business manager of *Metal Progress* and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management, etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business manager are: Publisher, American Society for Metals, 7301 Euclid Ave., Cleveland, Ohio; Editor, E. E. Thum, 7301 Euclid Ave., Cleveland, Ohio; Managing Editor, E. E. Thum, 7301 Euclid Ave., Cleveland, Ohio; Business Manager, Ray T. Bayless, 7301 Euclid Ave., Cleveland, Ohio.
2. That the owner is: The American Society for Metals, 7301 Euclid Ave., Cleveland, Ohio, which is an educational institution, the officers being, President, Bradley Stoughton; Vice-President, H. J. French; Secretary, W. H. Elsenman; Treasurer, F. B. Foley; Trustees: O. E. Harder, E. L. Bartholomew, C. Y. Clayton, K. R. Van Horn, N. F. Tisdale. All officers as above, address 7301 Euclid Ave., Cleveland, Ohio.
3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: None.
4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

Ray T. Bayless,
Business Manager.

(Seal)

Sworn to and subscribed before me this 8th day of October, 1942
Arthur T. Wehrle,
Notary Public.

(My commission expires Jan. 20, 1944)

Metal Science

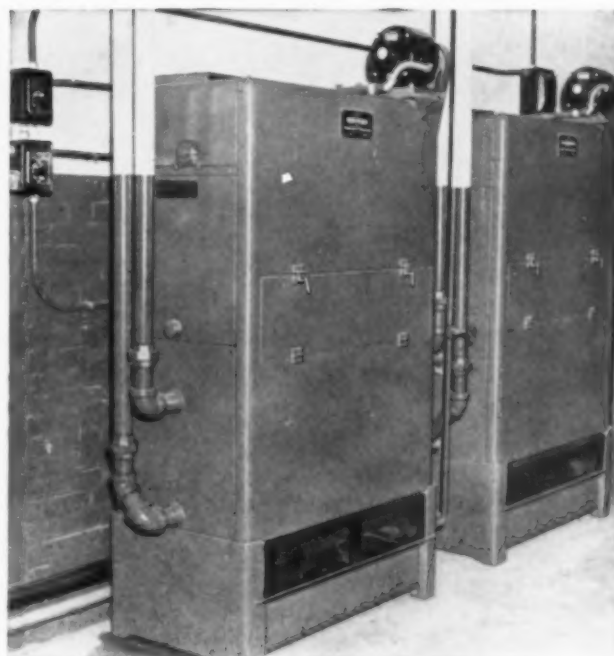
(Cont. from page 898) measured rates with various experimental conditions was explained on the basis of the diffusion rates of the hydrogen and water vapor involved in the reaction.

At the same session, EMERICK and FEIGENBAUM presented their paper on "The Duplex Process for Manufacture of Basic Openhearth Steel", which won the F. B. McKUNE memorial award for 1942. In it, they demonstrate that steels produced by this process can be made to the same quality standards as conventional openhearth heats. It was shown that nitrogen can be controlled by regulating the temperature of the blown metal, charge and control of the fill-up carbon, and subsequent rate of carbon elimination in the openhearth furnace. [Many of the above items are viewed from the standpoint of an openhearth operator, in Mr. NORRIS' report on page 879.]

Cold Work—Researches on problems of mechanical metallurgy were discussed in several sessions. In the first of two papers on notch effects, SACHS and LUBAHN showed that heat treated alloy steel tubing subjected to simultaneous longitudinal and circumferential tension failed at slightly higher tensile strengths, but with much lower circumferential ductility than rods of the same material tested in tension. Their second paper on notched bar tensile testing of similar steels showed that steels heat treated to tensile strengths over 200,000 psi. failed with practically no ductility when deep circumferential notches were cut in the specimens. In discussion, it was pointed out that the cohesion limit should always be considered to vary with the magnitude of all three principal stresses, rather than merely with the algebraically greatest stress. The notched bar test detects embrittlement by other factors, such as overheating, and the ordinary tensile test is of no avail in such cases. The general conclusion of these researches is that ordinary tensile test data do not provide criteria for the suitability of steels for parts having irregularities in shape similar to deep notches.

BARTHOLOMEW described studies on deep drawing and concluded that a useful index of drawability was the maximum value of the true stress during uniform elongation in the tensile

(Continued on page 954)



Niagara Aero Heat Exchangers in use by SKF

FASTER PRODUCTION OF HEAT-TREATED PARTS

**Secured by Accurate Control
of Quenching Temperature**

● Proper control of temperature... both by cooling the quenching bath during use and by heating it to proper temperature when cold... prevents spoilage, produces uniform physical properties and increases production speed.

Example: One manufacturer increased production from three to five units in the same time-period by installing the Niagara Aero Heat Exchanger in connection with his heat treat quenching.

If you have a problem of temperature of an industrial liquid, as in quenching, wire-drawing, broaching, rolling, wet grinding, hydraulic machinery, water-jacketed equipment, lubricants, coolants, chemicals or intermediates, the Niagara Aero Heat Exchanger offers positive automatic temperature control at lower cost. No cooling tower is needed; 95% of cooling water is saved. Closed system prevents contamination.

Write for Bulletin 90

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THE FOOTPRINTS OF GENERAL ALLOYS



Aug. 10, 1942
Ballston Lake New York

RECEIVED

AUG 11 1942

Q. A. CO. BOSTON

my father's name
Norman Borg Jones
He designs Electric
Furnaces.

He is a member of A. S. M.
I'd my brother Mike
and sister Katherine
have one too. Thank you

Martin Jones
Buell Heights
Ballston Lake
N. Y.

"Martie" Jones, age 7, wrote us for his "Adolf, das Schwein" piggy bank, offered in M. P. He remembers his brother and sister, Sister Katherine, age 11, sends us this poem in acknowledging her bank.



WE have been so busy with defense work, our problems, and the "Show" could not properly acknowledge the splendid response we got from hundreds of boys and girls in for their "Adolf das Schwein" banks to save for War Savings and Bonds. Mamas and Papis been writing us for years, but top the list. Their patriotic should set an example for adults everywhere. Martie's letter is brief and businesslike. He of his brother and sister. Katherine writes us a swell letter enclosing the good poem below.

ALL kinds of adults have chisel these banks, or for their kids, but, we know McCoy". We did make one that is, Bernie Zyniewski of New York. Bernie is a heat-treater at Watervliet Arsenal, and writes he is an "expectant father" requests a bank, which Bernie

WE have not space to print the names of all the children who have written in, but here are the first 50 received: Jerry Thomas, Royal Oak, Mich.; Dick Bronson, Detroit; David Weart, Seneca Falls, N. Y.; David Graff, Lockport, N. Y.; Keith Silver, Cincinnati, O.; Coralie A. Nash, Chicago, Ill.; Vincent Caporossi, Haledon, N. J.; Charlotte Anne, Ottawa, Ont.; Nancy Lee McKibben, Valparaiso, Ind.; Lindstrom, Webster Grove, Mo.; Isabella DiGiulio, Detroit; Joan Pethybridge, New Britain, Conn.; Karen Walner, O.; B. J. Adelson, Shaker Heights, O.; Madge Ann, Ferndale, Mich.; Thomas Norlie, Chicago, Ill.; Natalie Hamden, Conn.; Kay Lorraine Creager, South Bend, Ind.; Morrill, Pittsfield, Mass.; Carol Ann Beik, Chicago, Ill.; Basch, Batavia, N. Y.; Lewis Zink, Indianapolis, Ind.; Granquist, New Britain, Conn.; Erwin Grafwallner, M. Wis.; Jerry Lee Brenner, Lafayette, Ind.; Elizabeth Pottstown, Pa.; Mary Lou Rohrbach, Camden, N. J.; Ziegler, Kalamazoo, Mich.; Patricia Martin, Gary, Ind.; Cooper, Peoria, Ill.; Thelma Goodwin, Flint, Mich.; Mertens, Detroit, Mich.; Margaret Heinisch, Toledo, Ohio; Dauber, Utica, N. Y.; Grace Ann Honeychurch, Wharton, N. Y.; Philip C. Reilley, Pittsburgh, Pa.; George Hodgson, Jr., N. Y.; Tommy Lucas, West Allis, Wis.; Arlene Faykosh, Chicago, Ill.; Francis J. Newman, Mich.; Cecelia Sue Appel, Springfield, O.; Sydney Elizabeth Pennington, Shaker Heights, N. Y.; Lawrence Money, National Park, N. J.; David Atwood, Terryville, Conn.; Mimi Kahn, N. Y.; Eleanor Jean Slick, Muncie, Ind.; Leatha Fulkerson, Merchantville, N. J.; Loeb, Armond, N. Y.; Frances Asselin, Essexville, Mich.

REMEMBER

Remember the boys who have gone away
To fight for freedom night and day.
Remember too the war at sea,
Where sailors fought for you and me.

And then the sky was full of flames;
Of parachutes and burning planes.
But our boys are on the job again,
And will fight this war until the end.

Remember too "our" duty for Uncle Sam,
To buy a bond as fast as we can,
And then our boys will have plenty of supplies,
And come home smiling with victory their prize.

Katherine Jones
(Age 11)
Ballston Lake, New York.

THE "ENGINEERED ALLOYS" BOOTH AT THE CLEVELAND SHOW

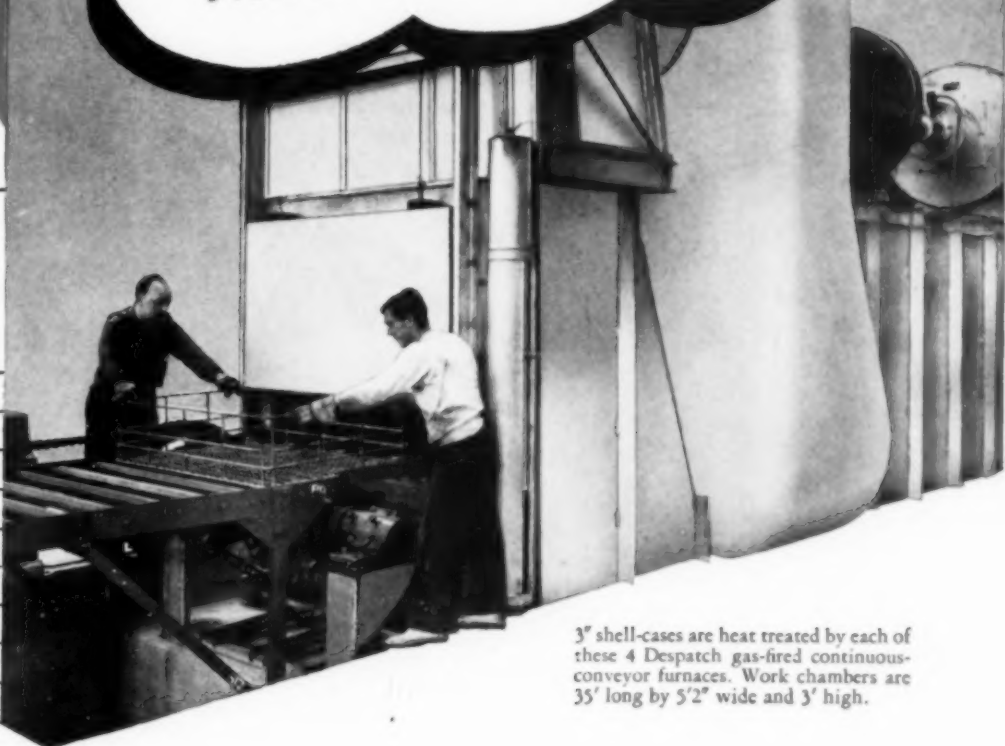


QALLOYS

THE QUALITY NAMES IN ALLOY
FOR HEAT CORROSION ABRASION

X-ite

WHY DESPATCH FURNACES DO FASTER HEAT TREATING



3" shell-cases are heat treated by each of these 4 Despatch gas-fired continuous-conveyor furnaces. Work chambers are 35' long by 5'2" wide and 3' high.

- ✓ AIRCRAFT PARTS
- ✓ TANK SECTIONS
- ✓ ARMOR PLATE
- ✓ SHELL CASES
- ✓ PROJECTILES
- ✓ GUN MOUNTS
- ✓ MACHINE TOOLS
- ✓ ENGINE PARTS
- ✓ Aluminum Alloys
- ✓ Bearings
- ✓ Castings
- ✓ Dies
- ✓ Gears
- ✓ Instruments
- ✓ Magnesium Alloy
- ✓ Pistons
- ✓ Punches
- ✓ Shafting
- ✓ Sprockets
- ✓ Taps
- ✓ Weldments
- ✓ Winches

Huge Air-Flow System Boosts Production

Why are Despatch furnaces able to heat-treat big loads so much *faster*? What is the reason for their *better production*? How is such *high quality* maintained on large-scale output?

The answer is found in Despatch's unique heat-flow system, where the use of larger, high-volume fans increases the movement of heated air enormously; *plus* improved methods of distributing this huge flow to reach every spot in the work chamber.

Best possible use is thus made of recirculated air, which passes through the load to give maximum penetration. This system offers truly outstanding advantages in speed, heat uniformity and fuel economy.

Fullest benefits from the speedy furnace are obtained by use of the most modern material-handling systems, with resulting savings in time, space and labor.

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WIRE TODAY**

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to recommend the furnace
to suit your requirements.
Free Bulletin No. 81 just
off the press; ask for it.

DESPATCH
OVEN COMPANY MINNEAPOLIS

New Equipment and Products

Portable Tensile Tester

Features of this testing machine have broadened the scope and utility of stress testing of materials, according to W. C. Dillon & Co., Chicago. This expansion of usability is particularly noticeable in the table model, an in-between-size instrument, with capacity for specimens up to 1 ft. long and 9 in. wide, and load up to 10,000 lb.

This versatility results from the use of the Dillon Dynamometer stress indicator, which is said to permit wide limits of measurement with a uniformly small stress-reader. Height starts at 32 in. for the table model to 78 in. for the floor type. Strength of any material may be determined so long as the breaking point of the specimen lies between zero and 15,000 lb.

Delivery: Reasonably prompt, according to priority supplied.

Finishing Wheels

New "MX" wheels, announced by the Carborundum Co. of Niagara Falls, N. Y., are made up of thin discs of cotton fibres intimately impregnated with either the uniformly graded grains of Aloxite Brand Aluminum Oxide or Carborundum Brand Silicon Carbide. These thin discs then are joined together in the form of wheels of various diameters and thicknesses. Wheels are so fabricated as to give variable degrees of resiliency and flexibility and are made in six grades of hardness.

Result is a clean, free cutting wheel giving at once a light stock removing and a high polishing action, the wheels requiring but little pressure. The harder grades

—No. 1, 2 and 3—are recommended on work that has a more severe action on the wheel. They are designed for such jobs as removing sharp burrs, or breaking down edges of gears. Grades 4, 5 and 6 are recommended for polishing small plane surfaces or areas.

New Welder

New alternating current welder, operating on a perfected electrical circuit which produces the proper voltage for every current setting, is announced by Allis-Chalmers Mfg. Co. of Milwaukee.

Designed to increase the efficiency and step up the speed of welding heavier, thicker metals, the transformer and reactor is built as an integral unit. Reactor coils surround the air gap, eliminating magnetic leakage. This arrangement is said to provide continuous control from 35 to 250 amperes. The new welder is built without plugs, taps or switches. Manual control at the top of the unit covers the entire welding range from maximum to minimum setting with a few turns of the control handle.

Stratosphere Chamber

To test the mechanical parts of aircraft as well as radio used in high altitude work, the Kold-Hold Mfg. Co. of Lansing, Mich., has developed a stratosphere chamber that operates between the temperatures of 200° F. above zero and 75° F. below zero, with an internal pressure variation 1 atmosphere down to 3 in. of mercury. Both pressure and temperature variations are controllable throughout their ranges.

This unit has an interior

chamber volume of approximately 245 cu.ft. and uses "Freon-12" as a refrigerant. The refrigeration effect, or heat acceptance from the chamber, is by forced convection through coils designed for low temperature work.

During a recent special showing, a test and research engineer for an aircraft company determined both output and input of their own product under stratospheric conditions. Results were obtained in only 4 hr. that would have taken days to accomplish under former methods of utilizing test pilots and a special plane.

New Fusion Welded Joint

New type of weld and welding procedure has been developed by W. K. Mitchell & Co., Inc. of Philadelphia, permitting fusion butt-welded joints to be made with complete penetration to the root of the weld. The method eliminates the backing rings or strips heretofore used in pipe joints, or places where welding can be done from one side only.

Tempilaq

Employing the same principle as Tempil pellets and Tempilstiks, a new product known as Tempilaq is available in a wide range of pre-determined melting points between 125 and 1600° F. Manufactured by the Tempil Corp. of New York City, Tempilaq is daubed on the working surface and dries in an instant. When the temperature stated on the container is reached, the smear liquefies sharply. On cooling, it solidifies, leaving a glossy or vitreous mark distinctively different from its original appearance. (Turn to page 946)



TENNAL

ALUMINUM CASTINGS

ARE GOING *"Over There"* IN PLANES...—TANKS...—SHIPS!

★ And we know our castings will give a very good account of themselves wherever they go, because each and every one of them meet all the specifications of the Army...—Navy...—Air Corps. Our ability to meet these rigid specifications with speed and quantity production is your guarantee of receiving quality sand and permanent mold aluminum castings when the victory is won.

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NEW YORK 111 Broadway • CHICAGO, 188 W. Randolph • DETROIT, Stephenson Bldg. • LOS ANGELES, 405 S. Hill
MAKERS OF QUALITY SAND AND PERMANENT MOLD ALUMINUM CASTINGS

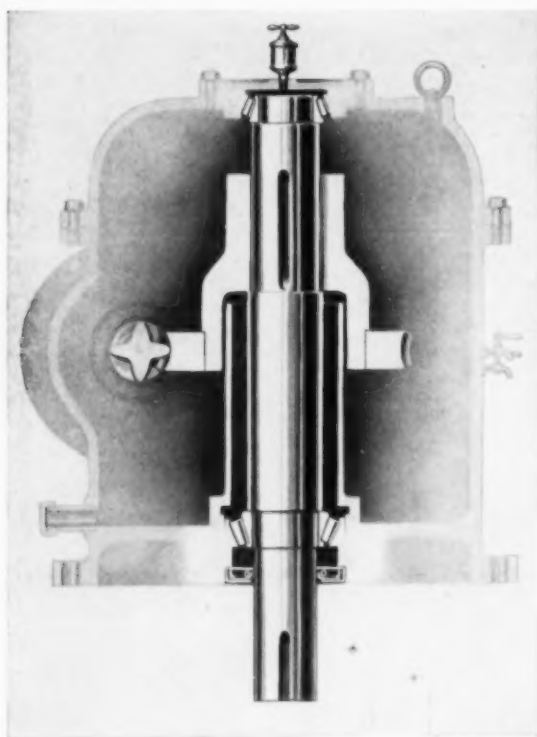
New Products

Molding Press

250-ton hydraulic press of the semi-automatic hot molding type with a completely electrically timed cycle was recently built by the E. W. Bliss Co. of Brooklyn.

The automatic cycle permits independent adjustment of the

lengths of preliminary cure, gassing period and the final cure. A variation of this control affords independent timing of a chilling period if required and an independent timing of the flushing of the mold passages at the completion of the cycle. Ability to change from the quick advance speed to the pressing speed before contact insures a gentle entrance into the mold, and is particularly good when working fine powders.



ELASTUF PENN Serves in the Rubber Program!

Hundreds of these agitator drives will perform vital operations in our rapidly accelerating synthetic rubber program. The shaft is the very heart of the drive—consequently much depends on the quality of the steel used. Shafts 4"-5" diameter are machined from Hot Rolled ELASTUF PENN Machinery Steel and used without heat treatment. High usable strength, freedom from distortion in machining, as well as in service, are all needed in the steel selected. ELASTUF PENN combines these qualities, with dependability and uniformity and it is available since it contains no critical alloys.

Learn more about ELASTUF PENN Machinery Steel—write for the booklet "ELASTUF STEELS IN ACTION."



ELASTUF STEELS

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BROWN-WALES CO. • BOSTON, MASS.-LEWISTON, ME.
HORACE T. POTTS CO. • PHILADELPHIA-BALTIMORE

Speedy Furnace Delivery

"Forty-nine days from idea to plant operation" is the speed record recently set by the Johnson Gas Appliance Co. of Cedar Rapids, Iowa, in producing a special heat treating furnace of large size. Its inside combustion chamber is 36 in. wide, 30 in. high and 60 in. long. It contains such features as an electrically operated door which raises in 5 sec. and stops automatically.

Brightening Steel

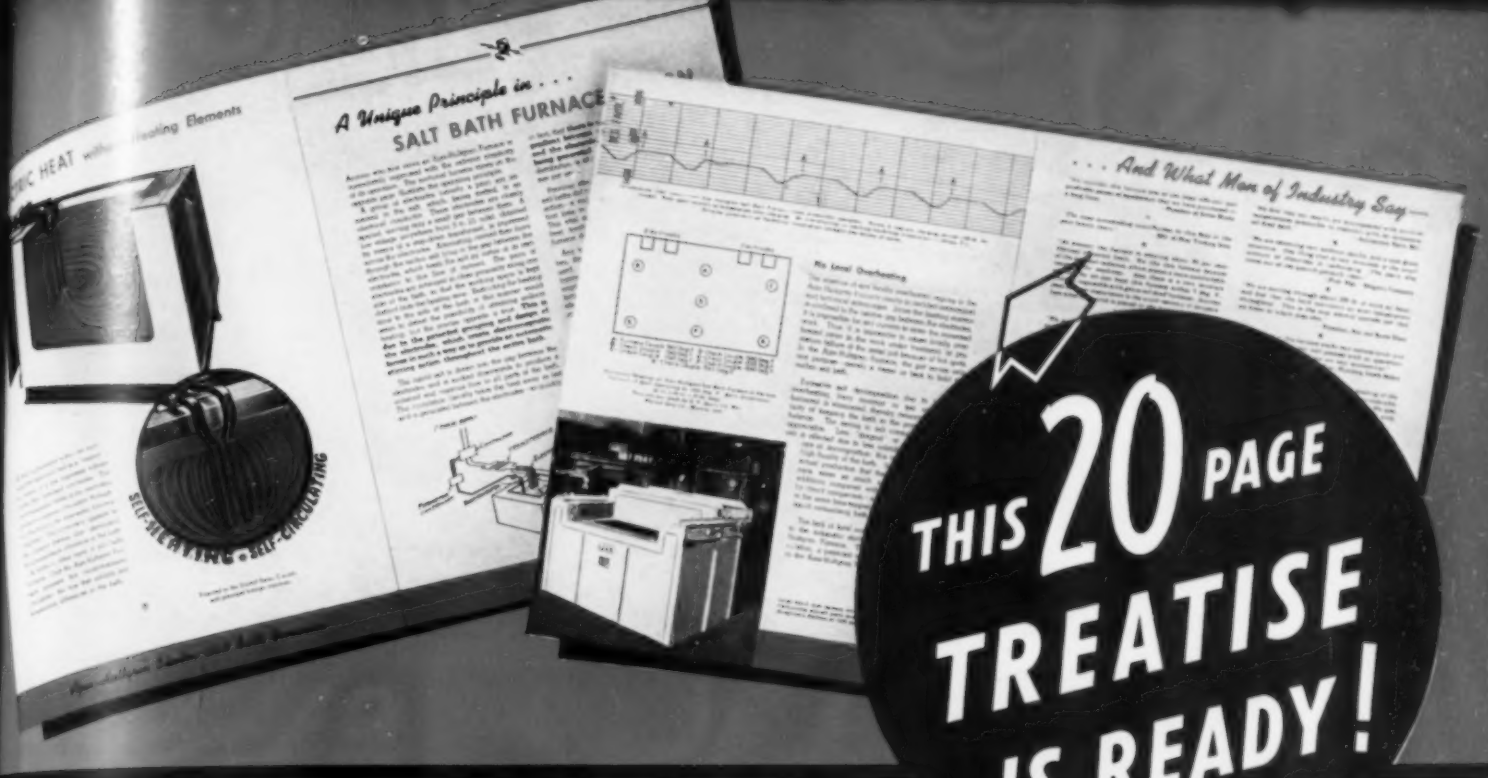
Surbrite, a steel surface conditioner, has just been announced by the Hanson-Van Winkle-Munning Co. of Matawan, N. J. A free-running powder, Surbrite is added to hydrochloric acid and sulphuric acid pickles. Its use in small quantities as additions to regular acid pickles produces bright, smut-free surfaces on iron and steel, and is said to reduce acid consumption and metal loss in comparison with pickling practice where plain acid is used without inhibitors.

Tool Bit Cuts Hard Metals

New line of tool bits for machining hard, tough steels and copper and aluminum alloys has been announced by Black Drill Co., Cleveland. These bits are made of the same metal that has proved its value in the patented "Hardsteel" drills and reamers. Many advantages are claimed for the material, such as greater shock-resistance than most cast or cemented tools and higher heat resistance.

New Temperature Control

So designed that it will actually warn an operator of an error in temperature selection, this automatic control for internally heated salt bath furnaces has been announced by the Upton Electric Furnace Division of Detroit. Claimed to be foolproof and simple in operation, its designers insist that even inexperienced workers can do high temperature heat treating with it, and get perfect results.



THIS 20 PAGE
TREATISE
IS READY!

"HEAT TREATMENT in Ajax-Hultgren ELECTRIC SALT BATH FURNACES"

SUBJECTS COVERED

- Basic Heat Treating Processes:**
- ANNEALING (wire, bars, stampings, etc.)
 - AGE HARDENING (aluminum alloys)
 - BRAZING
 - BRAZING AND CARBURIZING SIMULTANEOUSLY
 - CARBURIZING
 - CYANIDE HARDENING
 - DRAWING STEEL PARTS
 - HARDENING HIGH SPEED STEEL TOOLS
 - HEATING FOR FORGING
 - NEUTRAL HARDENING
 - SELECTIVE HEATING
 - TEMPERING STEEL PARTS

and

COSTS AND OPERATING PRINCIPLES:
 Ajax-Hultgren internal (electrode) heating principle . . .
 Automatic circulation of the bath . . . Thermal efficiency compared to fuels . . . Pot life . . . Maintenance costs . . . Automatic

temperature controls . . . Sizes, standard shipping dimensions, installation tables . . . Mechanized and Manual installations . . . Types of industry using electric salt bath furnaces . . . Performance reports . . . all are fully covered.

A great many executives are familiar with Ajax installations* for the standard liquid heat treating operations.

However, though over a thousand of these furnaces are in use, new high output processes developed exclusively by Ajax may be something of a revelation to many.

You will want to know something more about a furnace method which has been universally adopted by leading aircraft and armament makers for heat treating vital parts of engines, antiaircraft and machine gun parts, tanks, jeeps, army trucks, airplane structures, armor-piercing shot, high explosive shells, armor plate, steel cartridge cases . . .

There is up to date information in this publication which cannot fail to be of value to you or your staff. You may have it, without obligation, by writing:

AJAX ELECTRIC CO., INC. FRANKFORD AVE. AT DELAWARE AVE. PHILADELPHIA, PA.

*THERE'S AN AJAX INSTALLATION NEAR YOU!



THE **AJAX** ELECTRIC SALT BATH FURNACE
HULTGREN

ASSOCIATE COMPANIES: AJAX METAL COMPANY, Non-Ferrous Ingot Metal for Foundry Use
 AJAX ELECTRIC FURNACE CORPORATION, Ajax-Wyatt Induction Furnaces for Melting
 AJAX ELECTROTHERMIC CORPORATION, Ajax-Northrup Induction Furnaces for Melting, Heat-Treating

Congress

(Starts on page 895)

test. It was found that the stress in a drawn cup at a critical diameter where local necking or failure occurs is practically identical with the true stress at the maximum load point in the tensile test. Since this stress limits

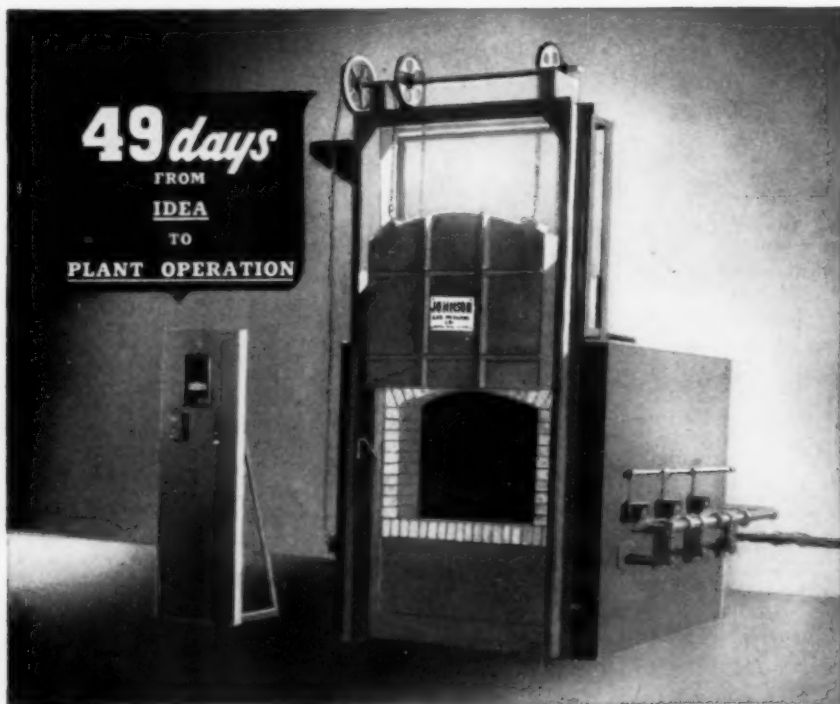
the maximum diameter of the blank that can be drawn into a cup, it is possible to predict this diameter from the tensile curves. Discussion brought out the fact that this correlation between tensile results and drawability would be altered by punch and die design, lubrication, hold-down pressure, speed, blank thickness, condition of combined stress. The recent series of articles in *Metal Progress* by engi-

neers in Lockheed Structural Research Laboratory may well be examined for a much fuller exposition of the problems of determining "drawability".

Two novel papers on cold working were presented to the at a week-end session. NICOXOFF showed that the maximum strain hardness obtained in austenitic manganese steels after any of a variety of heat treatments producing different structures was practically the same. Thus he concluded that none of the explanations for strain hardening in this alloy, based on decomposition of austenite to ferrite and carbide or to martensite, provides a complete answer. HERSCHMAN studied the surface hardness of medium carbon steel plate, cold rolled 1 to 2%. At 0.0003 in. and less below the surface he found a decrease in hardness which varied, however, with the original method of surfacing the plate. Thus, buffed and ground plates showed less pronounced decreases than polished plates because of the cold work induced by buffing.

Metal at High Temperature—Studies on deformation of steel at high temperatures were confined to few papers this year, but the results of a thorough research on a carbon-molybdenum grade were reported by MILLER, SMITH and KEHL. They showed that as the strain rate was decreased the tensile strength increased, and the elongation first increased and then decreased as the mode of fracture changed from transcrystalline to intergranular. It was concluded that this failure through the grain boundaries is normal at high temperature with slow rates of straining, and does not necessarily indicate deterioration and lack of plasticity preceding fracture. It was emphasized that the remaining sound metal may be just as ductile as it was originally. In discussion it was noted that.

(Continued on page 958)



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(Starts on page 895)

although these steels have less ductility in the pearlitic condition than after spheroidization, even a pearlitic structure will tend to spheroidize and improve in ductility after a stay at elevated temperatures.

MACGREGOR and WELCH presented a two-load method for deriving true stress-strain curves for various ferrous and non-ferrous alloys. They demonstrate that ductility at high temperature may best be pictured by the true uniform and the true local necking strains, and that the two usually are affected differently by the testing temperature; on the other hand, the true fracture and local necking strains are

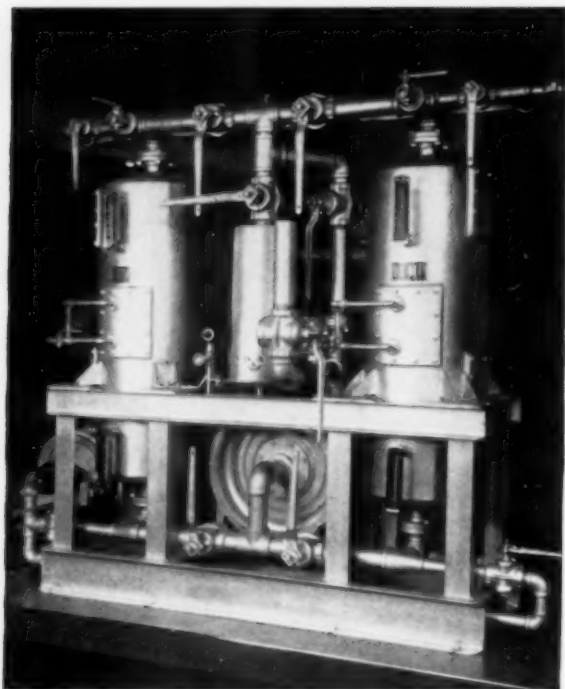
affected alike by temperature.

Surface Treatments—Carburizing, which once would have occupied several sessions, was represented by only one paper. MANNING's work with several common steels and solid carburizers indicated that higher carbon contents are obtained by higher carburizing temperatures, in spite of common suggestions to the contrary. Chromium tends to produce (and nickel oppose) very high carbon cases.

Another surfacing treatment was discussed by KRAMER and HAFNER in their paper on "Chromizing of Steel". They demonstrated that it is practical to chromize at 1650° F. with gaseous CrCl_2 produced by reaction of ferrochromium with HCl or BaCl_2 . While low carbon irons may be chromized readily, steels with as little as 0.20% carbon must also contain a sufficient amount of strong carbide-forming elements such as molybdenum to fix the carbon. Otherwise, the carbon diffuses toward the surface, forming a carbide barrier which stops the inward diffusion of chromium.

Galvanizing was represented by a paper in which ROWLAND and ROMIG describe a refined technique for polishing and etching to bring out the alloy layers developed. The use of a carefully prepared pure alumina suspension with pH controlled at 7 to 7.6 does the trick.

Life was finally brought into these meetings by CLARK and NUNGESTER who shocked many a weary ASMember (already baffled by cantankerous but inanimate metals) by showing that even a wee little sulphur bacterium, two microns long, can raise hell in a steel mill. He and his pals go through life converting sulphates to H_2S . Diabolically enough, they seem to prefer lines carrying cooling water; there they chew through the walls of a pipe faster than the mythical desert worm which destroyed so many steel rails. ☉



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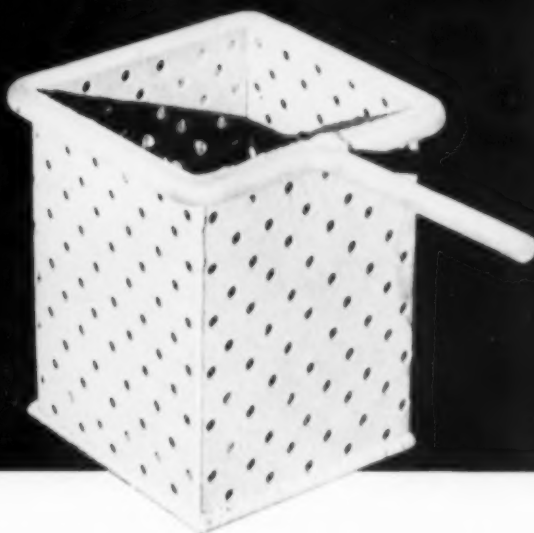
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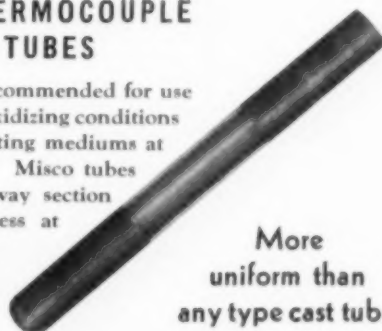
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November, 1942; Page 961

Oxidation of Copper★

■ RATE OF OXIDATION of copper has been very little studied at room temperatures owing to its slowness. In these new experiments electron diffraction patterns were used to measure the rate of the reaction between copper and pure, dry

oxygen at room temperature and 20 mm. pressure. Initial mean film thicknesses ranged from 20 to 100 Å.

Radii of the resulting diffraction rings are related to the spacings of the crystal planes by Bragg's equation, and the amount

of the chief constituent Cu_2O is judged by measuring the intensity of its principal lines.

Each specimen consisted of a film of copper vaporized upon a strip of plastic within the evacuated diffraction camera; the specimen was thus never exposed to the atmosphere. A weighed amount of copper was placed in a V-shaped tungsten ribbon directly below the specimen holder in the camera, which was exhausted and a diffraction pattern of the foil recorded. The holder was then rotated into a horizontal position and the copper vaporized by electrically heating the supporting tungsten. The mean thickness of the resulting film upon the thin supports may be calculated.

A diffraction pattern of the freshly prepared copper film was recorded at once upon the photographic plate, and the desired pressure of oxygen was then rapidly admitted to the camera. The reaction was allowed to proceed for about 2 min. before the oxygen was pumped out and a diffraction pattern again obtained, this time from the film in its partially oxidized condition. Oxygen was again admitted, and the entire process was repeated until the photographic plate was filled with patterns. The reaction time interval was progressively doubled, and at the end of a run the cumulative time of oxidation was 200 min.

Specimen and the undeveloped photographic plate were then left over night in oxygen, in order that a final pattern might be recorded after reaction for a cumulative total of about 1200 min. The standard pressure of oxygen for these experiments was 20 mm., but one run made at a (Continued on p. 964)

★Abstracted from "The Rate of Oxidation of Copper at Room Temperature", a paper by Addison H. White and Lester H. Germer for the Electrochemical Society, April 1942, published in Bell Telephone System Technical Publications, Chemistry Monograph B-1340.



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Oxidation

(Continued from page 962)

pressure of 4 mm. exhibited an unchanged rate of oxidation.

Microphotometer curves of diffraction patterns were used to measure the relative intensities of the (111) rings of Cu_2O and of copper on the various photo-

graphs. From this ratio was determined the fraction of the original copper specimen which had been oxidized when the pattern in question was recorded.

The diffraction patterns were used also to estimate dimensions of the Cu_2O crystals and of the cubic crystals of unoxidized copper which had been condensed on the supporting foil, prior to any oxidation. Their linear dimensions in directions normal

to the beam were 60 to 70 Å for copper and 30 to 40 Å for Cu_2O .

The results of all the tests upon the films of about 48 Å mean thickness can be represented by the equations

$$m/m_0 = a + b \log_{10}(t+c) \quad (1)$$

$$= b' \log_e (a't+c') \quad (2)$$

so that the equation for rate is

$$d(m/m_0)/dt = b'/(t+c) \quad (3)$$

where m_0 is the original mass of copper per unit area of film, m the mass of copper per unit area in the Cu_2O lattice, and t is the time of oxidation in min. always greater than 2 min. The rate-determining constant b of equation (1) is surprisingly reproducible, and equal to about 0.20, while c experimentally comes out as zero but must be a finite quantity since m/m_0 is intrinsically positive. The intercept a is very erratic, oxidation at the beginning being sensitive perhaps to the pressure of oxygen and of residual impurities.

Oxidation of the 90Å film can also be represented by equation (1) with a value 0.15 for constant b . This reduced value of the rate-determining constant is consistent with the smaller exposed surface per unit mass to be expected of a thicker specimen. Such an oxide film is protective, since after a certain lapse of time the rate of further oxidation is negligible.

It is concluded that at room temperature the oxidation for time greater than 2 min. proceeds according to equation (1) where m/m_0 is the fraction of the original copper which has been oxidized, and t is the time in minutes. Of the constants a , b and c , b is reproducible and c approaches zero. Using simple assumptions consistent with the size and shape of the copper crystals as inferred from the diffraction patterns, the thickness of the local oxide film is

$$x = 4 + 6.5 \log_{10} t \quad (4)$$

where t is measured in min. and x in Angstrom units. A limiting film thickness of about 50 Å is predicted by this equation. ☉

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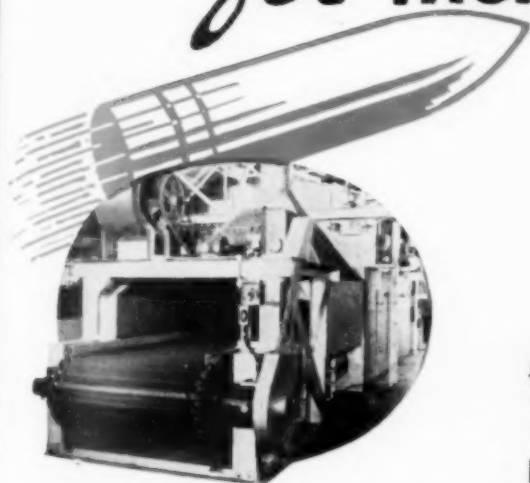
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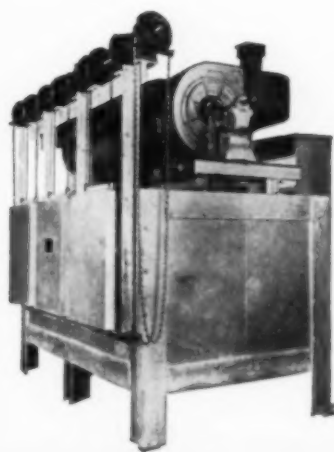


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Chromium Irons

(From p. 860) of 2 to 3% of silicon.

Reheating and rapid cooling tests clearly show that the brittleness is a reversible phenomenon and probably caused by a precipitation.

Change of Properties — There is an appreciable change in the

hardness of the alloys which have been subjected to the embrittling treatment. The low carbon chromium alloys containing 14 to 29% of chromium all had a similar Brinell hardness (140 to 150). After long-continued heating at 475° C. the hardness of the 14.7% chromium steel was unchanged; that of the 15.9% chromium alloy was slightly raised to 187, and that of the 28.7% chromium alloy

showed a marked increase to 321.

The acid resistance of the chromium-rich alloys suffers by the embrittlement treatment; loss of weight in a solution of copper sulphate in dilute sulphuric acid is ten times as great. Intercrystalline corrosion also occurs in chromium irons with 20 to 24% of chromium.

With reference to other physical properties, it was found that specific gravity, hardness, and coercivity increase, the magnetic saturation remains constant, while the electric resistance diminishes in the 24% chromium iron held at 875° F.

All these changes are consistent with the suggestion that the embrittlement is caused by some form of precipitation. It may be concluded that the phenomenon is not due to the action of any sort of carbide, since it is not affected either by carbon content or by the presence of strongly carbide-forming elements. It seems that the brittleness is dependent only on chromium content and hence on the precipitation of some iron-chromium compound. The only binary compound known is FeCr, the sigma phase, which, however, has not been detected in chromium-iron alloys with less than about 35% of chromium. This phase, moreover, is non-magnetic and its precipitation would involve a change in magnetic induction — which was not found to occur on embrittlement.

While the conditions for producing and for avoiding 875° brittleness are established, much remains to be done before an explanation of the phenomenon can be put forward.



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